Alteration of Volcanic Ashes on the Back-bone Mauntains in the Northeastern Section of Japan

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Introduction

A soil is a complex of mineral and organic substances. It is rather the product of development, or evolution, evolving from a parent material, which is the mantle rock, or regolith, and volcanics especially volcanic ash in volcanic regions. It is developed by slow processes, which include ordinary physical and chemical weathering, and in addition, some that go on only under the influence of living organisms. The organisms concerned include higher animals, earthworms, abundant form of microscopic life, and especially natural vegetation the remains of which have been deposited upon the within the surface soils. For this reason the soil is considered to extend downward so far as abundant organic life penetrates. Below the soil, whatever its thickness, is the parent material of the soil, and below that is solid rock.

Therefore, in the volcanic regions, the soil is derived by processes of weathering from the volcanics as a parent material, and therefore, it is necessary to distinguish between the processes that accumulate the parent material and those that make the soil.

However, the volcanic ash region in Japan is not so fertile in general. One of these reasons is the strong leaching of volcanic ash particles by precipitation, temperature and other factors.

The law of stability of rocks and minerals state that rocks and minerals are stable only in the environment of their formations, and as this environment surrounding the rocks and minerals which are relatively more nearly stable under the newer environment (Keller, 1957). The end products of weathering traditionally have been said to be red soil or laterite, a mixture of hydrated iron and aluminium oxides, or bauxite if the alumina content is relatively high, but to single out these materials as unequivocal end products or as end products in principle.

The fragmental concept for the definition of soil had been developed to the natural concept by Dokuchayev (Lenin Acad. Agr. Sci. USSR, 1949) and Glinka (1940) etc. According to their theories, soil is considered to be only a function of the external factors which are climate, landform, geologic materials, vegetation and artificial factors etc.

On the contrary to the above theory, the theory of Single Process of Soil Formation which soil will evolve by itself to fertilized soil without the external factors was pronounced by Williams (Kitagaki, 1953).

Soils, as we know them, have formed from many different kinds of rocks and volcanics found in the environment of different conditions. Volcanic ashes accumulated by volcanic explosions become the parent soil material in volcanic regions and their surrounding areas. Some of these volcanic ashes were originally loose, and some firm. Some of volcanic ashes have been carried by natural forces which are explosion, winds, running water and gravity etc. from one place to another. All volcanic ashes have formed by certain developmental processes, which are continuous, although they can be transformed in any place over long periods of time.

The weathering of volcanic ashes occurs in and around individual particles of ashes. Such as particles that have been leached, also iron which is included in a particle of the ashes as a chemical composition has been changed by oxidation, and thus exhibits a brown color. Oxidation is the process of weathering, a reaction by which the oxidizing substance loses the electrons to the oxygen that has become ionic. Furthermore, iron may occur in a high oxidation state (ferric) in two combinations; (1) with oxygen alone, as ferric oxide (hematite and limonite) and (2) as ferric ions in a silicate or other anion minerals.

A mineral in volcanic ashes which contains metal cations present at lower activities than the cations in water, undergoes dialysis when immersed in fresh water and tends to lose the metal cations in the process of establishing an equilibrium condition with the water. Hence, when a particle of ashes which contains the metal cations is immersed in rain water. Also, the movement of cations occurs by the contact exchange adjacent colloid particles (Jenny and Overstreet, 1939).

Hereupon, the writer attempts to explain of volcanics. Volcancis are classified into lava, volcanic fragmental materials and volcanic gas. Volcanic block, volcanic bomb, lapilli, volcanic sand, volcanic ash, volcanic dust, volcanic hair or Pelée's hair, pumice, scoria and volcanic debris etc. are included into volcanic fragmental materials. Lava and volcanic fragmental materials directly compose volcanic morphology in primary depositional surface.

Volcanic ashes are dusty to sandy fragments (less than 1 millimeters in grain size), consisting either of comminuted magma (glassy ash) or of pulverized rock material from the vent walls, or, as in the majority of cases, a mixture of both. In detailed studies it is necessary to carry out grain-size analyses, as it done in sedimentary petrography, and to determine the percentage of glassy ash in each individual size fraction. From the grains-zie analysis, the finest ashes may be separated from fine, medium, and coarse volcanic sands, the size boundaries being chosen analogously with those used in sedimentary grain analysis.

The general term that is applied to all volcanic fragmental materials that are transported by volcanic explosions and are subsequently deposited on the ground is pyroclastic rocks. The methods of transportation from an explosion crater are designated in terms of lava flow, pyroclastic fall, pyroclastic flow and volcanic mudflow etc. Pyroclastic falls are classified into ash fall, pumice fall and scoria fall etc., and pyroclastic flows are assorted as pumice flow, scoria flow and ash flow etc. Volcanic mudflows are classified into debris flow and mudflow.

Volcanic ashes weather very quickly and usually give rise to very fertile soil. In a few years a layer of humus will form on the surface of the ash, such brownish-black humus layers providing extremely valuable marker horizons in stratigraphical investigations of extinct volcanoes. Newly deposited glassy ash from basic magmas is generally blackish or grayish in color, but rapidly turns brown as a result of the oxidation of divalent iron.

The study consisted of map reading and laboratory working on topographical maps in the scale of 1:50000, and by field survey for the observations of materials, facies, distributions, soil profiles by hand borer, etc., also, laboratory experiments of the samples, etc.

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I A general view of the areas investigated

The areas investigated include more than several volcanoes of the back-bone mountains in the Northeastern Section of Japan, such as the Bandai, Zaō, Narugo, Onikōbe, Kurikoma, Iwate, Hachiman-tai and Hakkōda volcanoes etc. These are situated in the area enclosed by the parallels 37° and 41°N, and the meridians 140° and 141°E.

1 The Bandai volcanic area

The Bandai volcanoes rise up in the eastern part of the Aizu basin in Fukushima Prefecture, and consist of Bandai-san (1818.6 m.), Kushiga-miné (1636 m.), Akahani-yama (1427 m.) and some small peaks. The volcanoes are situated approximately at the parallel 37°35'N and meridian 140°10'E. Bandai-san and Kushiga-miné appear like twins. The volcanoes are of koni-tholoide shape geomorphologically. Also, there are several volcanoes in the western part of the Bandai volcanoes; such as Nekoma-dake (1404.5 m.), Umanodake-yama (1264 m)., Oguni-yama (1271.2 m.) and Kojōga-miné (1287.8 m.) etc.

The ejecta of the volcanoes consist primarily of two pyroxene andesite, and the upper parts of the mountain are mainly constituted by lava, however, colanic fragmental materials are extensively accumulated on the surrounding lower parts of the volcanoes. These cover the eroded surface of their foundation rocks which are composed of dacite and Tertiary sediments such as sandstone, siltstone and tuff etc.

The geological age of the first eruption of the volcanoes may be Pleistocene. Brown and black volcanic ashes are accumulated on the volcanic ejecta in the surrounding area of the volcanoes.

2 The Zao volcanic area

The Zaō volcanoes are located on the boundary between Miyagi and Yamagata Prefectures in the northeastern part of Japan, approximately at the central part of the area enclosed by the parallels 38°0' and 38°20'N, and the meridians 140°15' and 140°45'E. The volcanoes are topographically divided into two subgroup, north and south, along the Sumi-kawa and Nanba-zawa running respectively northeastwards and southwestwards through the central part of this area. The former area includes Kumano-dake (1840.8 m.), Katta-dake (1795 m.), Goshiki-dake (1674 m.), Jizō-san (1694 m.), Sanpōkōjin-san (1683 m.), Torikabuto-yama (1401 m.), Yokokura-yama (1151.9 m.), Nakamaru-yama (1557 m.), Sarukura-yama (873 m.), Ryu-zan (1363.5 m.), etc., whereas the latter consists of Sugiga-miné (1745.3 m.), Byobu-dake (1817.3 m.), Ushiro-eboshi-dake (1666 m.), Mae-eboshi-dake (1402.1

m.), Fubō-zan (1705.3 m.), Nyudō-zan (1600 m.), Manokami-dake (1585 m.), Nonomori (733.3 m.) and Aoso-yama (799.9 m.), etc. They are built of various kinds of ejecta and lava flows represented mainly by two pyroxene andesite, olivine-bearing two pyroxene andesite, and olivine two pyroxene andesite, forming konides or homates with several explosion craters. Such explosion craters were seomtimes the sources of mudflows.

The lava and ejecta of the Zaō volcanoes erupted on the eroded surface of the base rocks of granodiorite, aplite, pegmatite, plagioliparite, felsitic rocks, propylite, older andesite, and Tertiary sediments as shale, tuff, sandstone etc. The granodiorite of the Pre-Tertiary Period is exposed along the Yoko-gawa of the northeastern foot of Goshiki-dake, in an outcrop near the Kamoshika Spa, the Hanoki-zawa, and in the Gando-zawa from the northern side of Jizō-san to the western side of Gando-yama, and Myōgō-hō. Myōgō-hō consists of Granodiorite.

The Tertiary sediments are exposed along the Sumi-kawa, Nigori-gawa, Yoko-gawa, Zaō-gawa and the vicinity of the volcanoes. Some fossils of marine Mollusca were collected from the green tuffaceous quartz sandstone along the path and from the cliff in the vicinity of the Bus station about 700 meters above sea level near Sangai-taki (Sangai fall) of the Sumi-kawa during the field survey in July, 1960. These fossils are the following.

Clinocardium sp.,
Dosinia nomurai Otuka,
Glycymeris vestitoides Nomura,
Glycymeris sp. indet,
Ostrea? sp. indet,
Patinopecten kimurai (Yokoyama),
Placopecten? sp.,
Trachycardium shiobarense (Yokoyama),
Gryphus? sp.,

The sediments from which the fossils were collected are assigned to the Early Miocene and may correspond to the Moniwa member of the Hatadate formation in the vicinity of Snedai City. It is considered that the Zaō volcanoes erupted through the granodiorite basement and covered the Tertiary sediments. The first eruption may be in Pleistocene. It is inferred from field observations that the oldest lavas and ejecta of the volcanoes cover an alternation of beds of clay, sand and gravel which are referrable to the Pleistocene age.

There are several hundred settler's houses on the gentle slope at the eastern foot of the volcanoes, for exmaple Uenohara, Dofuyama, Shimizuhara, Nanokahara, Kitaharao, Misumi, Zaō, Fubō and Kawarako etc., and the cultured reclaimable land of this area totals more than 3,000 hectares. These settlers are raising barley, wheat, buckwheat, upland rice, paddy rice, oats, rye, soy beans, azuki beans, corn, potatoes, radish and livestock fodder etc. The Nanokahara area has been utilized as a stock farm since 1743, but most of the other were reclaimed after 1946.

Soil erosion and crop failures by high winds have become serious problems to settlers living on the reclaimed land at the eastern foot of the Zaō volcanoes. Soil erosion occurs when high winds come into contact with loose, unprotected volcanic ash in cultivated fields. Uncultivated fields that are well protected with vegetation do not eroded severely. The soil erosion by winds occurred under loose soil conditions and the lack of vegetation resulting from cultivation. The Typhoon No. 4 (Betty, May 1961) caused many stalks of barley and wheat plant to be borken, injured the potato plants, and the roots were exposed by erosion resulting in the death of the plants. The flowers of the rapeseed were injured and this resulted in the loss of the crop. Other plants as corns, upland rice and fodder were carried away with the topsoil by the winds. The barley harvest was reduced to 43 percent; potato, 84 percent; livestock fodder, 63 percent; and other crops to 46 percent compared with the average annual yield. Crop yields in this area were lowered as a result of severe soil erosion. Many fields lost several centimeters of topsoil during the year.

3 The Narugo volcanic area

The Naurgo volcanoes are situated in the south of Narugo Town, in the northwestern part of Miyagi Prefecture, approximately on the parallels 38°44'N and the meridians 140°43'. E. These small volcanoes are composed of three crests, named, Oga-dake (462 m.), Kurumi-dake (461.4 m.) and Toriya-ga-dake (396 m.).

The explosion crater lake "Kata-numa" is located at the foot of the volcanoes, and is surrounded by three crests. The acidity of the water of Kata-numa is the strongest in Japan, and now sulfur is being mined from the bottom of the lake.

The vegetation of the crests consist of grasses such as Graminaceae, Miscanths etc., and pine-tree, miscellaneous trees are now growing at the foot of the crests.

The crests are of tholoide shape. The lava of the volcanoes consist primarily of dacite which is called the Katanuma lava or the Kitakawa dacite (Onuki and Kitamura, 1962). This lava covers the upper part of the Akakura formation which consist of tuffaceous sandstone and shale with some fossil plants and lignite. The Akakura formation is assigned to the Upper Miocene (Ikeda, 1942).

There is a large explosion crater wall on the southwestern side of Kurumi-dake. It is a highly cliffed wall at its northern half. Some fumaroles are found in this area.

The geological age of the first eruption of the volcanoes may be Pleistocene as judged from the relationship between the lava and base rocks. It is unknown how many times volcanic activity took place in the area of Kata-numa during historic time. However, it is known that small activities occurred during the Jōwa era (A. D. 843–848). These were preceded by a rumbling noise (Miyagi-ken High School's Science Study Organization, 1963).

4 The Onikôbe volcanic area

The Onikōbe volcanoes rise up in the Onikōbe basin which is situated in the north of the Narugo volcanoes. The volcanoes consist of Arao-dake (984.2 m.), San-nō-mori (938.4 m.) and Takahinata-yama (769.1 m.), and are located approximately at the parallel 38°50'N, and meridian 140°43'E.

The Onikōbe basin was ever called a caldera from the view point of topography (Tsujimura, 1942), geology (Kobayashi, 1929) (Nakamura, 1956) and petrology (Katsui, 1955). However, the original form of the basin was formed by the crustal deformation, and deposited the lacustrine sediments in the Palaeo-lake (Omoto, 1964).

The basin is surrounded by such mountains as Kobuchi-yama (1261.7 m.), Katakura-mori (1040.6 m.), Sugane-dake (1243 m.), Takenoko-mori (1125.4 m.), Suzukura-mori (962 m.), Ōhira-yama (779.6 m.), Ōshiba-yama (1083.2 m.) and Koshiba-yama (1055.8 m.) etc. These mountains consist of green tuff and granodiorite, and rise up to about 1000 meters above sea level.

Arao-dake is situated nearly in the central part of the basin, and Takahinata-yama is on the southeastern side of Arao-dake. Arao-dake consists of hypersthene-adnesite and augite-andesite, whereas San-nō-mori and Takahinata-yama are built of dacite (Ikeda, 1942).

Several fumaroles are found in the geothermal areas of Katayama-jigoku, Arayu-jigoku and Megama-Ogama etc. Recent volcanic ash with laminations accumulates on the surface of the Katayama-jigoku geothermal area. This volcanic ash layer has a dark gray color, and includes plant leaves, opal etc. In view of these facts, this ash had been deposited in the paleo-lake in Holocene, and was influenced by solfataric action (Murayama, 1969).

5 The Kuriokma volcanic area

The Kurikoma volcanoes are situated in the boundaries of Miyagi, Iwate and Akita Prefectures. The main body of the volcanoes is called Kurikoma-yama among the folks in Kurihara County, Miyagi Prefecture, its name is taken from the shape of the remaining snow which is horse-shaped in early spring. The folks of Iwate Prefecture call the same volcanoes, Sukawa-dake, which means source of acidic water, and another name among the folks of Akita Prefecture is Dainichi-dake which means a mountain of the rising sun.

The volcanoes are situated approximately at the parallel 39°N and the meridian 140°50'E. The highest of the volcanoes is 1627 meters above sea level.

The vegetation of the volcanoes consist of beech-trees between approximately 500 to 1100 meters above sea level, and the area above this zone is covered by brushwoods and shrubs.

The volcanoes are of konide shape. There are several parasitic cones around the strato-volcano; These are named Zaru-mori on the north side, Kokuzō-zan and Oji-mori on the south side, and Yokone-dake on the east side. The presence of several explosion craters have been known on the main body of the volcanoes. Of these, three are characteristic explosion craters and are opened semi-circularly northwards and eastwards at the summit of the volcanoes. They are highly cliffed and walled by the accumulation of the lava flows. An explosion crater, which is now filled with water, is found at the northeast side of the summit of the volcanoes. It is called "Shin-funka-ko" or "Showa-ko" and is nearly circular in shape. This lake is surrounded by a highly cliffed wall at its northern half, where are found thick accumulations of ejecta and lava of the pre-existing explosion crater which opend semicircularly northwards. Tsurugi-yama, on the western side of the explosion crater lake is a central cone of the Kurikoma proper. Small fumaroles are found at the eastern foot of the central cone.

The lava and ejecta of the volcanoes consist primarily of two pyroxene andesite, and these cover the eroded surface of their foundation rocks which are composed of dacite and the Tertiary sediments. This geological relation can be observed in the deeply dissected area where the lava and ejecta of the volcanoes form high cliffs. The mudflow from the explosion crater consists of rock fragments of two pyroxene andesite with a matrix of brown volcanic ash. The cliffs of the explosion craters are built of an accumulation of lava flows.

The geological age of the first eruption of the volcanoes may be Pleistocene. The number of volcanic activities since the first eruption can be estimated by the layered accumulations of the ejecta. Brown volcanic ash is accumulated at the foot of the volcanoes. No black volcanic ash was found with colored minerals. The other volcanic areas investigated are covered by the black volcanic ash with colored minerals. However, there is no black volcanic ash in the Kurikoma volcanic area. This reason may be no remarkable volcanic activities which accumulated volcanic ashes during historic time. The color of the surface soil is black brown or dark brown because of the humus contained in it.

The number of volcanic activities in the area of the Kurikoma volcanoes since its first eruption remains unknown. The historic records compiled by the Meteorological Bureau (1959) shows that volcanic activity took place only twice and both were small. There are no records concerning the accumulation of the volcanic ashes.

(a) On February 3, 1774, a minor explosion occurred, according to the records of the Azuma feudal clan.

(b) On November 20, 1944, a muddy soil erupted from the northwestern slope of the summit of Kurikoma-yama at the altitude of 1280 meters above sea level. A small concavity was made by this explosion, which is now filled up with water. The muddy water flowed down along the Iwai River near Ichinoseki City from the 22nd of the same month and many fishes were killed by the poisonous water. However, historic records of volcanic activity are not so confided in details. The historic records are only helpful to know the volcanic land forms, distinction and distribution of the volcanic ashes etc. in the rough.

6 The Iwate volcanic area

The Iwate volcanoes rise up on the northwestern part of Iwate Prefecture, and are located approximately at the parallel 39°50'N and meridian 141°E.

The volcanoes consist of Yakushi-dake (2040.5 m.), Kurokura-yama (1568 m.), Ubakura-yama (1517.3 m.), Inukura-yama (1408 m.), Ōmatsukura-yama (1407.6 m.), Komatsukura-yama (1743 m.), Mitsuishi-yama (1463 m.), Komokko-yama (1465 m.), Ōfuka-dake (1541.4 m.), Genta-ga-dake (1541 m.), Kamikura-yama (1362 m.), Nakakura-yama (1372.9 m.), Shimokura-yama (1166.6 m.), Yuno-mori (1049.4 m.), Maru-mori (1152 m.) etc.

The ejecta of the volcanoes consist primarily of andesites, and the upper parts of the mountain are mainly of lava, however, volcanic fragmental materials are extensively accumulated on the surrounding lower parts of the volcanoes. These ejecta cover the eroded surface of the foundation rocks which are composed of the Tertiary sediments such as siltstone, shale and tuff etc. The geologecial age of the first eruption of the volcanoes may be Pleistocene. Brown and black volcanic ashes are accumulated on the mudflow materials and terrace plains in the surrounding area of the volcanoes.

The volcanoes here are topographically divided into two subgroups, the West Iwate volcanoes and East Iwate volcanoes. The both of the volcanoes are connected with Oniga-jō in the south side and Byobu-dake in the north side.

7 The Yake-yama volcanic area

The Yake-yama volcanoes are located in the eastern part of Akita Prefecture, and in the western part of the Hachiman-tai volcanic group. They are situated approximately at the parallel 40°N and the meridian 140°45'E. It is easily accessible from the Tamagawa and Goshogake Spas. The volcanoes are composed of Yake-yama (1366.1 m.), Kuroishi-mori (1231.2 m.) and Tsuga-mori (1349.7 m.) etc.

Yake-yama is a central cone of the volcanoes, and shows as a tholoide shape. Kuroishi-mori and Tsuga-mori are consisted as a somma. The ejecta of the volcanoes consist primarily of two pyroxene andesite, and the upper parts of Yake-yama are mainly constituted by lava and volcanic blocks. More than twenty of solfatara are opened in the bottom of the crater at Oniga-jō, Yake-yama. The crater has a cricular form with a diameter of about 300 meters, and is surrounded by a cliffed wall. The solfataric clay with whitish gray color is accumulated in the bottom. The lava and blocks near the solfataras are remarkably altered into white color by solfataric action and are traversed by small fissures out of which hot sulfur spring is abundantly flowing out. The surface of the ground around the extinct solfataras is thickly veiled with sublimed sulfur. The lava and ejecta of the volcanoes cover the eroded surface of their foundation rocks which are composed of welded tuff and the Tertiary sediments.

The number of volcanic activities in the area of the Yake-yama volcanoes since its first eruption remains unknown. The historic records complied by the Meteorological Bureau shows that volcanic activity took place several times.

(a) According to the old record "Tōgoku-Ryokō-Dan (Book of Travel in the Eastern Part of Japan)", the crater broke out in a remarkable explosion and looked like a large fire. So the volcano was named Yake-yama. Yake-yama means burning mountain.

(b) In 1887, a minor explosion occurred in the crater of Yake-yama.

(c) On August 30 and 31, 1949, minor explosions occurred and a mudflow rushed down from the crater of Yake-yama to the lower part. The mudflow spreaded about 80 centimeters in thickness and 200 meters in length.

At the present time, more than twenty of solfatara are emitting as superheated steam with a minor amount of hydrogen sulfide and sulfurous acid gases from the bottom of the crater, and throw up to about several ten meters in height with a rumbling nosie.

The Tamagawa Spa is located at the western foot of Yake-yama and in the upper stream of Shibukuro-zawa. The emissions of solfatara in this area are the largest scale in the Hachiman-tai Spa group.

Recent lapilli and volcanic sands are widely accumulated on the surrace of Yake-yama as a central cone and its surrounding area. These ejecta are well exposed on the cliff and summit. The occurrence of such ejecta can easily be recognized at a distance, because the area has a dark gray or light gray. The lapilli are represented by angular fragments of two pyroxene andesite, comonly 0.5 centimeters to 3 centimeters in diameter. Most of these fragments have a light gray color, but there are frequently porous or compact andesites with a light gray or dark gray color. Volcanic sands consist of plagioclase, augite, hypersthene, magnetite as well as of tuffaceous substance and minute fragments of two pyroxene andesite.

Also, Yake-yama consists of lava flows and volcanic blocks, showing various colors such as black brown, dark gray, dark brown and whitish gray etc. Whitish gray or white colored volcanic blocks are intensely subjected to the solfataric action.

There is a series of smaller steam-spouts in the southern part of the Gosho-gake Spa. Their activity is subject to wide fluctuations. Here and there new steam-spouts arise, throwing the muddy ground water into the air rather like a geyser. Hot fumarole gases break through the muddy ground water in a caldron-like depression, and keep it in seething movement.

There are many spas around Yake-yama. The Fukeno-yu, Ōbuka, Gosho-gake and Ōnuma Spas are located on the eastern flank. The Tama-gawa Spa is located at the western foot. The Aka-gawa and Sumi-kawa Spas are situated on the northern slope of Yake-yama. These hot springs contain abundant hydrogen sulfide and dissolved salt etc. Hot springs in this area bring dissolved silica to the surface, which on cooling is deposited in the form of sinter terraces.

8 The Hachiman-tai volcanic area

The Hachiman-tai volcanoes are situated in the northwestern corner of Iwate Prefecture, and enclosed approximately by the parallels 39°50' and 40°0'N, and meridians 140°45' and 141°0' E. The volcanoes are composed of the summit of Hachiman-tai (1613.6 m.), Mokko-dake (1577.8 m.), Genta-mori (1600 m.), Chausu-dake (1578.3 m.) and Appi-dake (1458.2 m.) etc. These volcanic bodies show as aspite shapes topographically, however, Mokko-dake shows remarkably a tholodie shape.

There are more than ten lakes in the Hachiman-tai volcanic area. Two explosion craters, which are now filled up with water, are found at the eastern side of the summit of Hachiman-tai. They are called "Hachiman-numa" and "Gama-numa". Hachiman-numa has an oblong form with about 350 meters in long diameter and about 80 meters in short diameter. Gama-numa has a nearly circular form with a diameter of about 60 meters.

The volcanic bodies are built up of lava flows, mudflow materials and ejecta represented mainly by two pyroxene andesite. These volcanic materials cover the eroded surface of their foundation rocks which are composed of welded tuff and the

Tertiary sediments.

It is unknown how many times volcanic activity occurred in the Hachiman-tai volcanic area since its first eruption. This may be also said of the volcanic activities in historic time, because there is no historic records concerning the Hachiman-tai volcanoes.

The main volcanic body of Hachiman-tai is surrounded by lesser cones and also by mountain peaks carved by erosion in the massive uplifts of which the volcanoes are a part. These volcanoes are made more gentle by the widespread distribution of volcanoes. However, the volcanic bodies are attacked by the agents of erosion and have features caused by them.

Brown volcanic ash is widely accumulated on the upper part of the volcanic area.

The vegetation in the volcanic area consists of various kinds of alpine plants. These plants are the following.

Abies Mariesii Masters,
Pinus pumila Regel,
Ledum palustre Linnaes var. *diversipilosum* Nakai,
Rhododendron Fauriae Franchet var. *roseum* Nakai,
Arcterica nana Makino,
Empetrum nigrum Linnaeus var. *japanicum* K. Koch,
Fagus crenata Blume,
Botrychium lunaria Swartz,
Botrychium robustum Underwood,
Adiantum nipponicum Hance,
Osmunda cinnamomea Linnaeus var. *fokiensis* Copeland,
Osmunda japonica Thunberg, etc.

9 The Hakkôda volcanic area

The Hakkōda volcanoes are situated approximately in the central part of Aomori Prefecture, and enclosed by the parallels 40°45' and 40°35'N, and the meridians 140°45' and 141°0'E. The volcanoes here are topographically divided into subgroups, north and south, along the Ara-kawa and Tsuta-gawa running respectively northwestwards and southeastwards through the central part of this area. The former includes Tamoyachi-dake (1324 m.), Akakura-dake (1548 m.), Ido-dake (1550 m.), Mae-dake (1525 m.), Ō-take (1585 m.), Hina-dake (1240 m.), Takada-ō-take (1551 m.) and Ishikura-dake (1205 m.) etc., whereas the latter consists of Akakura-dake (1278 m.), Komaga-miné (1416 m.), Kushiga-miné (1518 m.), Yoko-dake (1339 m.) and Minamizawa-dake (1199 m.) etc.

They are built up of various kinds of ejecta and lava flows represented mainly two pyroxene andesite, olivine-bearing basaltic andesite and pyroxene basaltic andesite etc. forming konides and tholodies with several explosion craters, large or small. Such explosion craters were sometimes the soruces of large mudflows, as can be seen in the areas of the Suka-yu and Yachi Spas etc.

The ejecta and lava are very complicatedly distributed and overlapped, because they erupted repeatedly from many centers. Some of these restupon such base rocks as the Tertiary sediments and dacite etc.

The approach to the volcanic bodies is easily from the Tashiro, Suka-yu, Shin-yu, Yachi and Sarukura Spas etc. And it is conveniently to reach to the spas by the motor coaches from Aomori and Towada Cities. There are many swamps such as Tashirotai, Kenashitai, Sennintai, Takadayachi and Yachi swamps. Many explosion craters are found on the summits and finaks of the volcanoes, however, there are no historic records concerning volcanic activity of the Hakkōda volcanoes.

Various kinds of alpine plants are found in the volcanoes. These plants are the follows.

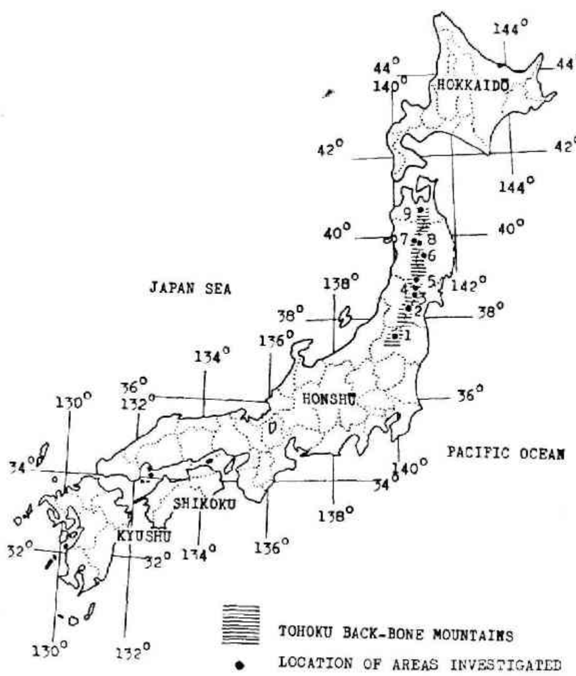

Fig. 1 Locations of Areas Investigated in Japan.
1–Bandai, 2–Zaô, 3–Narugo, 4–Onikôbe, 5–Kurikoma, 6–Iwate, 7–Yake-yama, 8–Hachiman-tai, 9–Hakkôda volcanoes

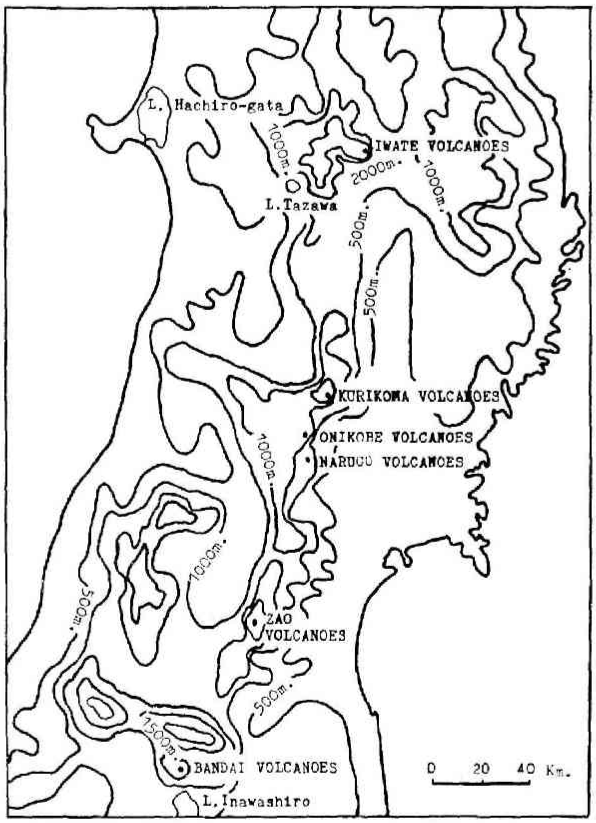

Fig. 2 Summit Level of the Areas Investigated in Northeastern Japan.

Abies Mariesii Masters,
Pinus pumila Regel,
Betula Ermani Chamisso,
Fagus crenata Blume.
Rubus vernus Nakai,
Empetrum nigrum Linnaes var. *japonicum* K. Koch,
Acer Tschonoskii Maximowicz,
Ledum palustre Linnaeus var. *diversipilosum* Nakai,
Miscanthus sinensis Andersson, etc.

II Formation of the volcanic bodies

1 The Bandai volcanic area

The volcanic ejecta which form the main bodies of each volcano in the Bandai volcanoes are inferred to have been made of the alternation of lava and volcanic fragmental materials. These fragmental materials ejected during explosive activity are known as pyroclastic materials, volcanic dust, volcanic ash, volcanic sand, lapilli, scoria, bombs and blocks are terms indicating increasing size which are applied to such materials. A good outcrop is the explosion crater wall of Kushiga-miné, where the northern side of Bandai-san was blown off abruptly and formed a U-shaped sharp cliff toward the north, about several hundred meters in height. And other exposures are to be seen at the explosion crater of the Nekoma volcanoes, and dissected V-shaped radial valleys.

The Bandai volcanoes are represented by Bandai-san. And the other volcanoes in this area are composed of Akahani-yama, Kushiga-miné and some small peaks. The Nekoma volcanoes are situated in the western part of the Bandai volcanoes, and is represented by Nekoma-dake. These volcanoes include Oguni-yama, Umanodake-yama, Kojōga-miné, Futago-yama and some small peaks. The central cones of these volcanoes are built up of lava and such fragmental materials as agglomerate, lapilli, sand and ash which are well stratified and have varying colors. The lava and fragmental materials are very complicatedly distributed and overlapped, because they erupted repeatedly from many centers. These ejecta erupted on the eroded surface of the base rocks composed of granodiorite and Tertiary rocks of sandstone, siltstone, green tuff and dacite etc. This geological relation is recognized in the deeply dissected area. The granodiorite is sporadically exposed along the Kawageta fault line which extends from north to south along the eastern side of the volcanoes. The granodiorite is the most predominant rock covered by the Tertiary sediments. The Tertiary sediments are found around Lake Hibara, Lake Onogawa and Lake Akimoto etc. Dacite is sporadically exposed at the northern side and southern side of the volcanoes. One of the good exposures is at the western coast of Lake Inawashiro.

Younger fluviatile deposits of the Quaternary are seen along the present river course such as the Nagase-gawa, Ōshio-gawa and Nippashi-gawa etc. where they consist of clay, sand and gravel. Younger fluviatile deposits are accumulated on the volcanic ejecta at the foot of the volcanoes. By the geological relation, the geological age of the first eruption of these volcanoes may be Pleistocene. It is inferred from the fact that the lava and fragmental materials of the Nekoma and Bandai volcanoes erupted together, and the oldest mudflow of both volcanoes are that have been with unconformity underlain by the alternation beds of sandstone, siltstone and tuff etc. that have been assigned to the Pleistocene.

Some huge explosions occurred after the main bodies were formed. The volcanic land form of the area at present except the Ura-bandai area was mainly formed during this stage. Many huge explosions occurred in the volcanoes, and volcanic mudflows flowed down to the lower parts of the volcanic areas.

The present Necoma volcanic area is composed of somma, caldera having a diameter of about 2.5 kilometers and the Oguni atrio-lake. The Yūshi-zawa stream is now flowing down from the Oguni atrio-lake to Lake Hibara via the crater lake in the northern part of the somma. Therefore, the Yūshi-zawa is considered to be a barranco. The somma is constructed of the Necoma-dake, Umanodake-yama, Kojōga-miné, Futago-yama, Oguni-yama and other crests. The volcanic fragmental materials deposited around the somma comprise volcanic block and lapilli with a matrix of brown volcanic ash and sand.

The Bandai volcanoes are composed of the three peaks of Bandai-san, Akahani-yama and Kushiga-miné. There are some volcanic mudflow areas which were reported already in the vicinity of the volcanoes (Tanabe, 1960) (Furuya, 1965a). They are called the Okinajima mudflow and Biwazawa mudflow etc.

(1) Okinajima mudflow

The soruce of the Okinajima mudflow is presumed to be from the pre-existing crater at the southern slope of Bandai-san and the western slope of Akahani-yama. The mudflow extends widely from the Okinajima area to the northeastern area of Aizu City. This mudflow rushed down towards the south and changed its direction at Hanita to flow twoards the northwest like a U-turn. It also flowed down towards the south at Odera and spread towards the south in fan-shape. In this area, large and small flowmounds were formed by this mudflow (Mizuno, 1958). Also, this mudflow dammed Lake Inawashiro. The mudflow was composed of angular andesite blocks which are over several ten centimeters in diameter and a matrix of brown volcanic ash or sand. These materials are veiled by the brown volcanic ash, and the black volcanic ash accumulated on the surface of the earth. The brown volcanic ash deposited measured 20–80 centimeters in thickness and the black volcanic ash 10–70 centimeters in thickness in this mudflow area.

(2) Biwazawa mudflow

The Biwazawa mudflow rushed down from the Numano-taira explosion crater which is opened semi-circularly twoards the east among the three peaks, Bandai-san, Akahani-yama and Kushiga-miné. Numano-taira formed as an explosion caldera, is seen as an atrio. Two atrio lakes and one crater lake called Kagamiga-ike exist in this area. This mudflow extends along the Biwa-zawa which flows down from a col of Numano-taira to the Nagase-gawa on the eastern flank of the Bandai volcanoes. The western side of Akahani-yama is a long steep slope formed as a wall of the Numano-taira caldera. This mudoflw is deeply dissected and highly cliffed by the Biwa-zawa, and well exposed along the Biwa-zawa, and also along the left bank of the Nagase-gawa near Mi-ne Village, Inawashiro Town.

The mudflow is composed of angular or subangular andesite blocks of several ten centimeters in general and sometimes more than 2 meters in diameter, and of lapilli with a matrix of brown volcanic ash and sand.

(3) Ura-bandai mudflow

The Ura-bandai mudflow occurred in 1888. The main body of shō-bandai-san was destroyed, and approximately 670 meters from the bottom to the top in relative height and 1.7×10^9 cubic meters in volume of the collapse were carried down towards the north, and dammed the old Nagase River (Meteorological Bureau, 1959). The mark of the collapse is preserved as a U-shaped explosion crater wall about several hundred meters in height. The bed of lava, ash, sand and lapilli exposed in this cliff is well stratified and inclines to the north at an angle of 10°–20° at both sleeves. The different volcanic sediments are accumulated alternately and show various colors such as gray, dark brown, dark red and black etc.

The mudflow deposit is composed of fresh and angular andesite debris and block with a matrix of volcanic ash, sand and lapilli. The colors of the matrix are dark red, dark brown, brown, dark gray and blackish gray etc. The mudflow materials are generally accumulated in the northern area of the crater wall.

An explosion caldera was formed and is now preserved as an atrio at the ruins of the collapse, and spreads fan-shaped twoards the north from the crater wall. There are some atrio-lakes in this caldera.

2 The Zaô volcanic area

The volcanic ejecta which form the main bodies of each volcano consist mainly of lava and deposits of an alternation of lava and volcanic fragmental materials. These volcanic ejecta rest upon the eroded surface of base rocks composed of granodiorite, aplite, pegmatite, plagioliparite, basalt, older andesite and Tertiary sediments etc. These geological features are seen at the deeply dissected areas where lavas and volcanic fragmental materials of the Zaō volcanoes are highly cliffed. In this fact, the Tertiary formation covers the eroded surface of granodiorite etc.

The first eruption which formed the main bodies of the Zaō volcanic group is supposed to have commenced originally from Aoso volcano, and the activity

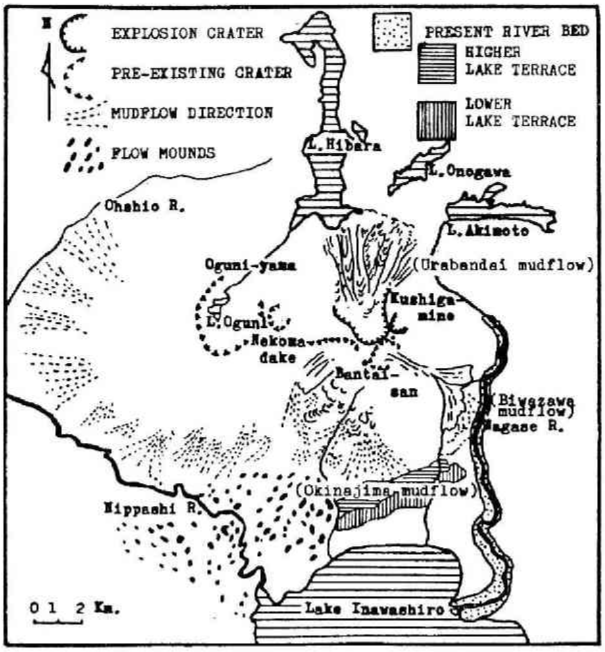

Fig. 3 Geomorphological Map of the Bandai and Nekoma Volcanoes.

migrated to the south Zaō volcanoes in order (Ichimura, 1953) (Furuya, 1965b).

(1) Aoso volcano

The Aoso volcano is located near the northern corner of Katta County, Miyagi Prefecture. This volcano is included in the Zaō volcanic group and rises at the eastern end of the south Zaō volcanoes. It is a small composite volcano and isolated from the main part of the Zaō volcanoes, being bordered by the Akiyama-zawa, Matsu-kawa and Kosute-gawa. This volcano rest upon the rocks of Tertiary age and lacustrine deposits, and is composed of Aoso-yama (799.9 m.), Ōmori-yama (800 m.), Takakura-yama (666.1 m.), Tōmori-yama (564 m.), etc. It is dissected deeply by the Akamatsu-zawa, Dō-zawa, Onashi-zawa, Namin-zawa, Taiko-zawa and Itabashi-zawa. The summit of Aoso-yama is accessible from such villages Miya, Magatake, Teppō-chō, Nagano, Kotumazaka, Tōgata and Kitaharao.

The present Aoso volcano is composed of somma and central cones, but it seems to have been a characteristic homate in the earlier stage of its activity. The volcanic body is constructed by mudflows, two pyroxene andesite and agglomerate etc. It rests upon the base rocks, and there is an evidence that the mudflows directly cover the flat surface. Younger or older fluviatile deposits are distributed along the present river courses. These fluviatile deposits are composed of gravel, sand and clay, and cover the mudflow materials.

The base roks of the Aoso volcano are composed of sedimentary rocks, agglomerate, andesite all of Tertiary age and lacustrine deposits of Quaternary age, etc. There is, however, no exposure of granodiorite which is commonly seen at the base of the other parts of the Zaō volcanoes. The Tertiary formation exposed in the cliffs of the dissected area due to erosion of the rivers at the foot of the volcano consist mostly of shale, sandstone and tuff, but alternating beds of sand and clay are also represented. Shale, sandstone and tuff are extensively exposed on the hills extending northwards or eastwards of this volcano. Characteristic outcrops of the Tertiary shale and sandstone beds can be seen near Miya and Magatake. In the former case, the eastern extention of the shale and sandstone beds dips below the covering of volcanic ejecta. Tuff is a common rock in the area and, is well developed in and around Tōgatta and Kotsumazaka. Generally, it has a light green color on fresh surface, and its weathered surface is grayish white. Those rocks have some lithological similarities to other rocks which have been assigned to Miocene in the adjoining areas. The horizontal beds of clay, sand and gravel are exposed in the cliff near the Tōgatta Generating Plant along the southern side of the Matsu-kawa. Of these sediments, the gravel bed contains such pebbles as of granodiorite, basalt, andesite, dacite, propylite, granite-gneiss, quartzite, tuff, etc. The beds were probably formed in a lake. The almost flat surface of these beds is covered by mudflows pumice layers and lava flows. The andesitic agglomerate seen on the hill behind Kotsumazaka and Iboiwa, and remarkably at Ibiwa along the bus road between Nagano and Tōgatta, contains angular or subangular fragments that range in size mostly from several centimeters to 20 centimeters in diameter.

The Aoso volcano rests upon the eroded surface of these Tertiary rocks. The first eruption seems to have taken place in Pleistocene. The volcano is composed of lava and various kinds of ejecta which rest upon the Tertiary formation already mentioned. The Aoso volcanic ejecta comprise the Matsu-kawa mudflow, Dōzawa lava and agglomerate, Tōmori-yama lava, Onashi-zawa lava, Itabashi-zawa agglomerate and Ōmori-yama lava in the order of eruption.

The Matsu-kawa mudflow is supposed to have poured out from the preexisting crater at the earliest stage of activity. The northern end of this mudflow is highly cliffed along the Matsu-kawa and the lower course of the Akiyama-zawa where it is underlain by nearly horizontal beds of the lacustrine deposits of clay, sand and gravel. Lava flows mostly of two pyroxene andesite and associated with this mudflow are seen in the cliff of the Akiyama-zawa.

The Dō-zawa lava extends from south to north, forming a narrow ridge between the Dōzawa and Onashi-zawa. The northern end of this lava flow is highly cliffed along the Matsu-kawa, but the lower disappear beneath the Tōmori-yama lava southwards and is supposed to have been supplied from a pre-existing crater.

The Tōmori-yama is widely exposed around the central cones of Aoso volcano and forms a part of somma which is now dissected deeply by the Itabashi-zawa, Taiko-zawa, Namin-zawa, Onashi-zawa, Dō-zawwa, Akamatsu-zawa etc.

The Itabashi-zawa agglomerate is exposed along the Itabashi-zawa. It contains abundant fragments of dacite, both large and samll. This agglomerate is covered by the Ōmori-yama lava and seems to have been the forerunner of the lava which formed the central cones.

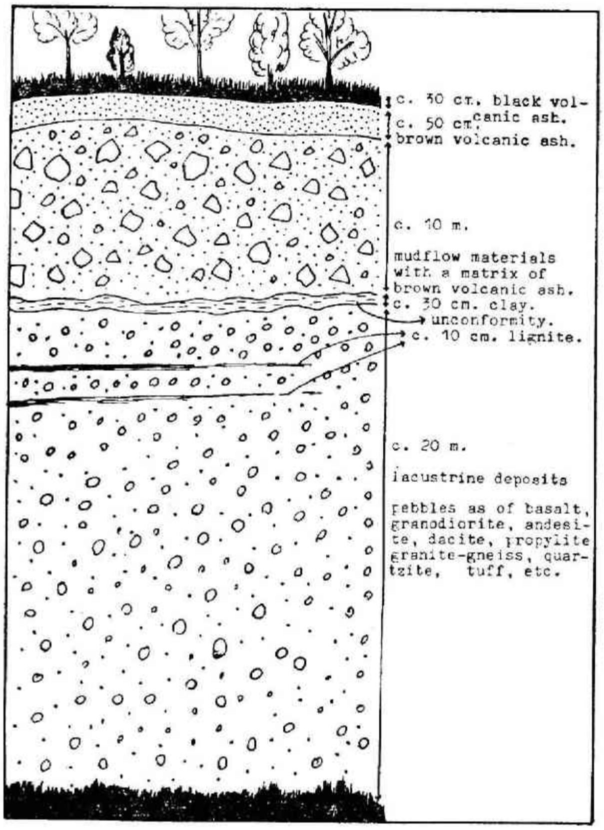

Fig. 4 A Sketch of the Cliff near the Tôgatta Generating Plant along the Southern Side of the Matsu-kawa.

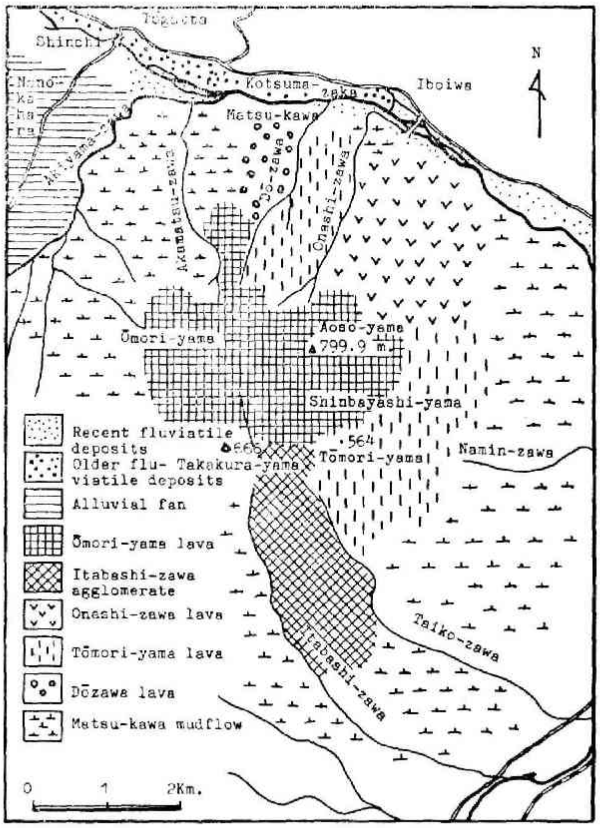

Fig. 5 Geological Map of the Aoso Volcanic Area.

The Ōmori-yama lava rests directly on the Itabashi-zawa agglomerate and Tōmori-yama lava.

Present Aoso volcano is composed of somma and central cones, but it seems to have been a characteristic homate. Such cones as Takakura-yama, Tōmori-yama, Shinbayashi-yama etc. seem to have been formed on the peripheral part of the crater. There are several explosion craters on Aoso volcano. They are respectively found on the northern and southern sides of the central cones, and the southern flank of Takakura-yama as well as on the northern side of a cone situated about 1 kilometer northwest of the summit of Aoso-yama. Two of them are characteristic explosion craters opened semicircularly northwards and northeastwards. The other explosion craters of those central cones are situated at the opposite side of the above characteristic explosion craters. The explosion craters of Takakura-yama are smaller and older than those of the central cones. The

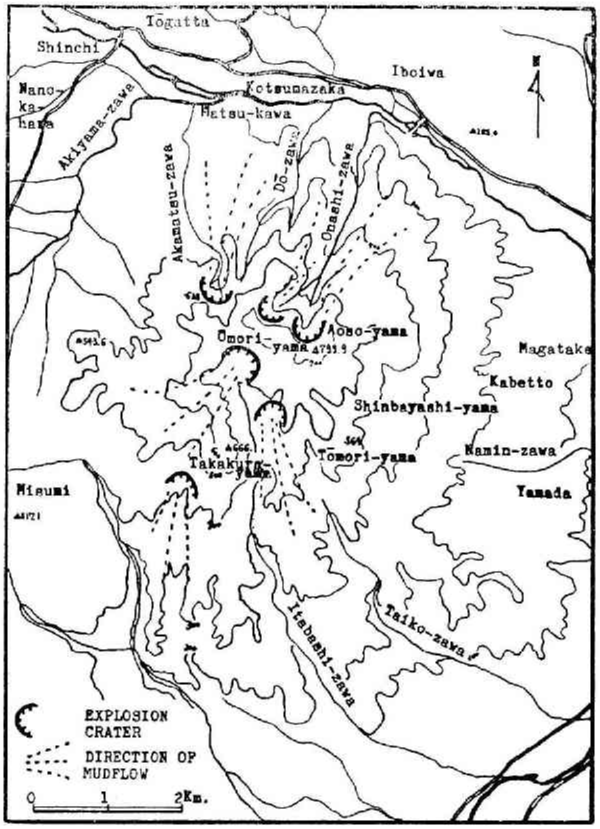

Fig. 6 Topographical Map of the Aoso Volcanoes.

former exploded southwards on the southern flank of Takakura-yama. The latter is still preserved as a horse-shoe shaped hollow on the northern slope of the cone. The mudflows which are thought to have poured out from these explosion craters are seen in the cliffs of the dissected areas.

(2) The south Zaō volcanoes

The south Zaō volcanoes are represented by Byobu-dake, Fubō-zan, Sugigaminè, Ushiro-eboshi-dake, Mae-eboshi-dake, Nyudō-zan, Manokami-dake and Nono-mori. The south Zaō volcanoes are separated from the north Zaō volcanoes by the Sumi-kawa and Nanba-zawa.

These volanoes are built of lava, agglomerate and mudflow. The lavas and ejecta of the south Zaō volcanoes erupted and covered the eroded surface of the base rocks composed of granodiorite, basalt, older andesite and Tertiary sediments.

This geological relation can be observed in the cliffs of the deeply dissected area of lavas and ejecta of these volcanoes. The granodiorite is sporadically exposed along the Sumi-kawa as well as along the Yoko-gawa. The best exposure can be seen in the bed of the streams called Yoko-gawa, Ōyanagi-zawa, Koyanagi-zawa, Nanba-zawa, etc. The highest point of exposure is seen in the upper course of the Nanba-zawa, where the granodiorite outcrops at an altitude of more than 1300 meters above sea level. This fact undoubtedly suggests that the lava and ejecta supplied from the south Zaō volcanoes were not thickly accumulated. The granodiorite is the most predominant rock covered by the Tertiary sediments as well as by the older and younger andesites. The Tertiary sediments are found near Fudō-taki of the Sumi-kawa and along the lower course of the Namari-zawa running down southwards from near the summit of Fubō-zan. The older andesite is exposed at the western corner of Byobu-dake and it is distributed westwards. It seems that the lava flow is underlain by granodiorite and overlain by green tuff. Its thickness is estimated to be approximately 1300 meters. The lava and ejecta of the south Zaō volcanoes are intricately overlapped and the eruptions were repeated in this volcanic area. The ejecta are called the Sumi-kawa lava and agglomerate, Nono-mori agglomerate, Buobu-dake lava, Fubō-zan lava and ejecta, Sugiga-mine lava and agglomerate, Ushiro-eboshi-dake lava and ejecta, Nyudō-zan lava and agglomerate and Manokami-dake lava.

The first eruption of the south Zaō volcanoes seems to have occurred at the eastern part of this volcanic area where the crater of Nono-mori is found on the hilly land between the Akiyama-zawa and Tashiro-zawa. The agglomerate exposed there extends northwards to Hakuundai, where it is overlain by the Nanokahara alluvial fan on its east and by the Sumi-kawa lava and agglomerate, Ushiro-eboshi-dake lava and ejecta and Manokami-dake lava on its west respectively. A good outcrop can be seen along the middle course of the Akiyama-zawa, where is exposed angular fragments of two pyroxene andesite, large or small, cemented with tuffaceous or sandy matrix.

The Sumi-kawa lava and agglomerate outcrop at the northern part of Byobu-dake and are dissected deeply by theNigori-gawa, Sumi-kawa and Kowatera-zawa. Of these, the lava flow gentle dips norhwards or northeastwards. It is highly cliffed along the Nigori-gawa and Sumi-kawa. The agglomerate is well exposed in the cliff near Fudō-taki and Sangai-taki. The Sumi-kawa lava and agglomerate are thought to have been supplied from a pre-existing crater which is now Nyudō-zan lava and agglomerate. The eruption of the Byobu-dake lava occurred later than those of the Sumi-kawa lava and agglomerate, although it poured out from the same pre-existing crater. The lava flow extends down to the uppermost course of the Sumi-kawa northwards and to the Yoko-gawa southwestwards.

The lava flows and ejecta from Fubō-zan exposed on the base rocks composed of granodiorite and green tuff etc., rise up to 1705.3 meters above sea level.

The Byobu-dake lava is covered by the Sugiga-mine lava and agglomerate which source was on the western flank of Sugiga-miné in close association with agglomerate underlain by the Tertiary andesite and Pre-Tertiary granodiorite of the Yoko-gawa.

The Ushiro-eboshi-dake lava and ejecta partly cover the Sumi-kawa lava and agglomerate or Nono-mori agglomerate, and built there the Ushiro-eboshi-dake and Mae-eboshi-dake. The lava is thought to have been erupted from the crater which had similarly been the source of the Sumi-kawa lava and aggolmerate.

Nyudō-zan is composed of lava and agglomerate that erupted from a pre-existing crater where it was born as a central cone. The basal part of these volcanic products is agglomerate which is exposed along the uppermost course of the Akiyama-zawa.

The Manokami-dake lava extends from east to west and builds Manokami-dake, being bordered by the Akiyama-zawa at the north and the Kara-sawa at the south. This lava is exposed at the northern flank of Manokami-dake where it is deeply dissected and highly cliffed by rapid erosion of the Akiyama-zawa. This lava seems to have poured out from the pre-existing crater after the eruption of the Nyudō-zan lava and agglomerate.

Byobu-dake is shown as an aspite geomorphologically, and rises up to 1817.1 meters above sea level as the main part of the volcano. One of the huge explosion crater walls is seen at the eastern side of Byobu-dake (Murayama, 1959), but its summit is flat and spreads in three directions with gentle slopes from the summit of the main part westwards at the western side of the volcano. This explosion crater wall is a sharp cliff from the top to its foot, measuring several hundred meters in height and about 1.5 kilometers from the south edge to the north extremity in width. At the foot of the volcano, there is developed a gentle open slope in the shape of a triangle, and about 2 square kilometers in area. This sharp cliff seems to be a fault cliff, however, there are no precise field evidences to determine it as a fault cliff so far as the topographical investigations are concerned.

Concerning this subject, it is necessary to consider the formation of Nanokahara fan with regard to the sharp cliff of Byobu-dake. The apex of the Nanokahara fan is situated at about 5 kilometers east of the sharp cliff of Byobu-dake. This fan spreads eastwards and forms a gentle slope of 7°–14°, and measured approximately 3.5 kilometers from the apex to the edge.

It is important to understand the process in development of the Nanokahara fan in order to recognize the general developmental processes of the other phenomena in the volcanic area. In previous publications concering the formation of the fan, several views have been presented, for instance, "tilted block topography" by Shoji (1950), and "mudflow" by Ichimura (1955), Furuya (1965b) and Mizuno (1964) etc. However, there is no certain evidence to regard the Nanokahafa fan as a tilted block. According to Ichimura (1955), the Nnokahara fan was formed by mudflow. The source of this mudflow is the explosion crater of Numa just beneath the summit of Mae-eboshi-dake. The mudflow which rushed down from the northeast through the narrow between the southern branch of Mae-eboshi-dake and eastern end of Manokami-dake, formed a large fan-shaped slope now called Nanokahara. Furuya also took the same view as Ichimura, and supposed that the rounded stones in the open wells of the fan are the gravels of a river bed along older river in Nanokahara.

The rapids of the Akiyama-zawa, which commence from the foot of Byobu-dake to the lower part, flows down through the narrow valley between the southern branch of Mae-eboshi-dake and the eastern end of Manokami-dake, and turns southwards at an angle of about 50° at the apex of the fan. It flows along the north side of the fan, then flows into the Matsu-kawa at Kozumazaka as an accordant junction. Several rapids, for instance, the Sukehiro-bori, Naga-sawa, Batō-zawa, Sumigama-zawa, Tsukinoki-zawa, Yahatsukasa-zawa etc. flow from the apex, or near there, as an anastomosing course. These rapids gush from underground sources. The sharp cliff of Byobu-dake was formed by the Bandai type explosion after being built on the erodded surface of the base rocks. The structure of Byobu-dake is made more complicate by the lavas and ejecta that erupted from other sources. This geological feature is shown in the deeply dissected area where lavas and ejecta of the Byobu-dake are highly cliffed. Half of the eastern side of Byobu-dake was blown away, and thereby numerous rock fragments accumulated through the agency of the explosion on the eastern side of this volcano. These rock fragments have been transported by running water over a long period of time during Holocene, and now extend from the higher area to the lower part of the area. These rock fragments which were transported southeastwards through the narrow valley between the southern branch of Mae-eboshi-dake and the eastern end of Manokami-dake, formed a large fan-shaped slope now called "Nanokahara". Topographically, this characteristic feature can easily be distinguished. After the formation of the fanglomerate, mudflow rushed down from the explosion crater of Numa just beneath the summit of Mae-eboshi-dake. The mudflow extended to the lower areas along the Akiyama-zawa and made a thin cover the fanglomerate, and also formed two small hills at the north end of the fan near the Hakuundai colony. The fanglomerate under the angular gravelly soil horizon is an accumulation of rounded stones of augite andesite and two pyroxene andesite of dark gray or black color with remarkably porphyritic texure. They are composed of plagioclase, augite, hypersthene, magnetite etc. embeded in the groundmass with a pilotaxitic texture. The various characteristics of these ingredients are almost the same as those of the rock fragments in the Akiyama-zawa and Byobu-dake. These rounded stones accumulated in a layer about 30 meters in thickness and cover the Tertiary formation, and fine grained sands fill the interspaces between the rounded stones. These rounded stones are a product of flowing water, and were transported from the eastern side of Byobu-dake, to accumulate in the river bed to form a fanglomerate.

Some pieces of burnt wood (carbonized wood) of the Coniferae were found at the southern side of the Akiyama-zawa. These burnt Coniferae woods were buried in the brown volcanic ash at about 1.5 meters from the surface with samll angular stones. These woods are inferred to have been burnt by the hot ashes of the volcanism and to have been transported down with small angular stones by the agency of explostion. By this reason, the fanglomerate of Nanokahara was veiled by the mudflow from Numa. The explostion crater of Numa is one of the remarkable explostion craters of the area and the mudflow poured out during the last stage of activity after formation of the fanglomerate at Nanokahara. The explosion crater here is semicircularly surrounded by a steep wall of approximately 200 meters high from its bottom on the southern flank of Mae-eboshi-dake. Its diameter is 1200 meters from east to west, and bout 1000 meters from north to south. It opens southwards, and is filled up with an accumulation of mudflows. In this mudflow area of Numa, the surface of the area is thickly covered by a forest of beech and is adorned with many small swamps from which the name "Numa" was taken.

Another explostion crater seems to have been opened farther up the Akiyama-zawa. But, it was subjected intensely to the subsequent erosion of the Akiyama-zawa and its tributaries. There is also a similar crater at the source of the O-sawa. It is situated behind Nyudō-zan and is semicircularly walled by Byobu-dake and Fubō-zan, although its inner part is intricately dissected by the O-sawa with an underlation of Chochoga-mori. The highest point of this wall is estimated to be about 400 meters above the bottom of the main valley. Also, several explosion craters are located on the southern flank of Fubō-zan. They are scattered here and there, some of them being found near the crest line between its summit and the south Byobu-dake. Such explosion craters are represented by horse-shoe shaped or semicircular hollows opend mostly southwards or southwestwards. The largest one is located downwards from near the summit of Fubō-zan and is surrounded by a wall composed of thickly accumulated lavas and agglomerates which dip aporoximately 30° southwards. Moreover, the presence of a large explosion crater is noticed at the uppermost course of the Nanba-zawa, being

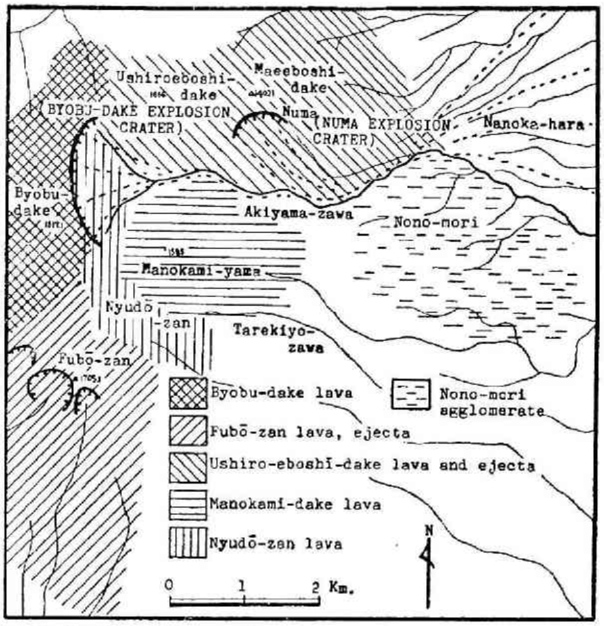

Fig. 7 Geological Map of the South Zaô Volcanoes.

situated between Sugiga-miné and Katta-dake. It has a diameter of about 1500 meters from northwest to southeast. It is about 300 meters high above its bottom, where granodiorite and Tertiary sediments are exposed. A small explosion crater is also known on the southern flank of Nyudō-zan.

(3) The north Zaō volcanoes

The north Zaō volcanoes include Kumano-dake, Katta-dake, Goshiki-dake, Jizō-zan, Sanpōkōjin-san, Torikabuto-yama, Yokokura-yama, Nakamaru-yama, Sarukura-yama, Ryu-zan, etc. They are built of various kinds of ejecta and lava flow represented mainly by two pyroxene andesite, olivine-bearing two pyroxene andesite, and olivine two pyroxene andesite (Ichimura, 1951).

The north Zaō group is underlain by Tertiary sediments and Pre-Tertiary granodiorite. The Tertiary formation covers the eroded surface of granodiorite, and is composed mostly of green tuff, conglomerate and shale. The lava and ejecta form konides or homates with several large or small explosion craters. The Tertiary sediments and Pre-Tertiary granodiorite are the base rocks exposed in the cliffs along the Nigori-gawa, Sumi-kawa, Yoko-kawa and Zaō-gawa.

The Yokokura-yama lava and agglomerate rest upon the Tertiary andesite and green tuff, and construct here the Yokokura-yama at the northwestern end of the north Zaō volcanoes. This lava is characterized by the predominance of platy joints.

The Hiyamizu-yama lava which builds Hiyamizu-yama covers the Yokokura-yama lava and Tertiary andesite.

The Jizō-zan lava which makes Jizō-zan, covers the Yokokura-yama lava, Ryu-zan lava and granodiorite.

The Kumano-dake lava consists of several flows of lava, and builds up Kumano-dake. The north Zaō volcanoes is represented by Kumano-dake which rises up to 1840.8 meters above sea level. The lava flows and ejecta exposed here are bedded alternately. The upper part of the lava flow is composed of the calc-alkali rock series, and the lower part is of the tholeiitic rock series (Chiba, 1961). The upper part of the lava flow is exposed at the southern part of Kumano-dake, and extends to the western part of Katta-dake. The lower part of the lava flow is exposed at the western part of Kumano-dake, and lies underneath the Umanose ejecta.

Katta-dake is composed of the Katta-dake lava that erupted alternately from a pre-existing crater, and now forms a konide shape, geomorphologically.

There is a large explosion crater at the southern end of north Zaō surrounded by Kumano-dake and Haizuka-yama. The crater is a semicircular hollow with a diameter of about 2 kilometers from northwest to southeast and is opened northeastwards. The larger part of the wall is highly cliffed down to the bottom where Goshiki-dake rises up as a central cone characterized by the presence of a small crater lake at its western foot. The pre-existing crater here seems to have been largely destroyed by the next explosion. Goshiki-dake rests upon the eroded surface of lava flows or ejecta which had their soruces in the pre-existing crater. It is deeply dissected and highly cliffed along the O-sawa and in the vicinity.

An explosion crater, which is now filled up with water, is located at the western side of Goshiki-dake. It is called "Okama" or "Goshiki-numa" and has a nearly circular shape with a diameter of about 300 meters. This crater lake is surrounded by a highly cliffed wall at its eastern half, where thickly accumulated ejecta are well exposed.

Also, there is a large explosion crater at the northern end of the north Zaō volcanoes surrounded by Sanpōkōjin-zan, Torikabuto-yama, etc. The crater is a semicircular hollow with a diameter of more than 1 kilometer from north to south and is opened westwards toward Zaō Town, Yamagata Prefecture. It was formed by the destruction of a pre-existing crater. The explosion crater wall is highly cliffed at the eastern side of the crater, and exposes alternating beds of lava flow, agglomerate etc.

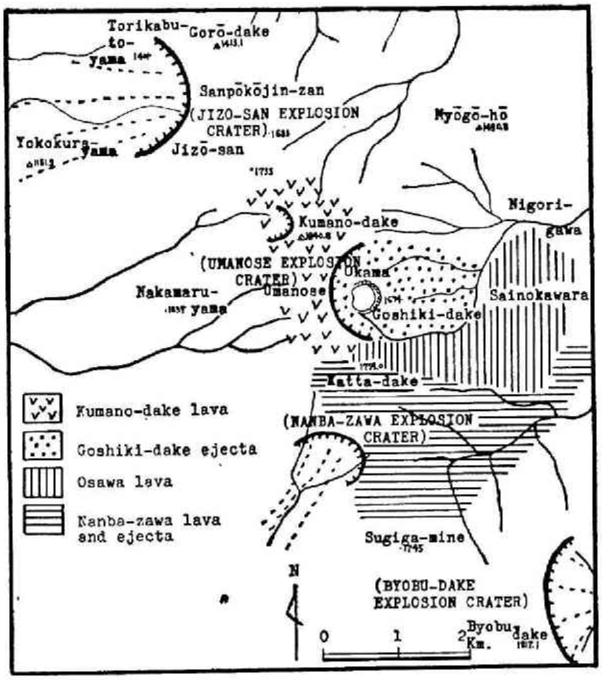

Fig. 8 Geological Map of the North Zaô Volcanoes.

3 The Narugo volcanic area

The volcanic ejecta which formed the three crests in this stage is mainly of lava. The lava of Oga-dake and Kurumi-dake consist of dacite, however, the lava of Toriyaga-dake is hypersthene-bearing plaigo-ryolite (Ikeda, 1942). This lava is underlain by the upper part of the Akakura formation which consist of tuffaceous sandstone and shale. Also, the outcrop of granite or granodiorite are seen in the cliffs along the Arao-gawa near the Narugo Dam in the northwestern part, or at the southern part of the volcanoes. They are well exposed in the dissected cliff extending northwestwards or southwards from the volcanoes. The Tertiary formation can be seen to cover the eroded surface of granite or granodiorite of which age is considered to be Pre-Tertiary. The lava of Kata-numa (dacite) which consists of Oga-dake and Kurumi-dake has a dark gray color and assumes a gray or reddish brown color on weathered surface, its phenocrysts are composed of quartz and pyroxene.

After the three crests were formed, huge explosions occurred and formed mudflow areas in the surrounding areas of the volcanoes. The explosion crater which is called Kata-numa and the explosion crater wall on the southwestern side of

Kurumi-dake were formed in this stage. The Kata-numa, which is now filled up with water, has a nearly circular form with a diameter of about 450 meters.

Mudflows from Kata-numa spread around Kata-numa, also, are supposed to have poured out from this crater to the southwestern side, and are widely spread at the edge of the mudflow area between the Takino-yu Spa and Numai. Mudflow materials are exposed at many places. Remarkable exposures are seen at the cliffs of the quarry near Kata-numa and also along the Arao-gawa. The mudflow materials consisted of subangular or angular dacite blocks of several centimeters to 2 meters in diameter, and have yellow or yellowish brown volcanic ashes as a matrix. These accumulated to a thickness of more than ten meters. The blocks have such varying colors as gray, dark gray and light gray etc.

The Narugo mudflow seems to have poured out from the soruce which is supposed to have successively supplied from the Kurumi-dake area. It flowed down northwards widely over the area including Narugo Town, probably in contact with Kata-numa mudflow. The mudflow materials consisted of subangular dacite lapilli and blocks of 1–60 centimeters in diameter and yellow or yellowish brown volcanic ashes as a matrix. The exposures are seen along the Arao-gawa and some cliffs in the Narugo Town area.

4 The Onikobe volcanic area

The volcanic products which form the main bodies of each volcano consist mainly of lava. The first eruption which formed the main bodies of the Onikōbe volcanic group is supposed to have begun from Arao-dake, then moved to Sannō-mori, and finally formed Takahinata-yama. The order of eruption is divided into volcanic mudflow, Iwana-zawa lava, Sannō-mori-zawa lava and Takahinata-yama lava in the order stated (Kato and Shimada, 1953).

The original form of the Onikōbe basin was formed by the crustal deformation. And, the geological age of the first volcanic activity in the basin is supposed to be from Pliocene to Pleistocene, and erupted lava and agglomerate from Arao-dake on the lacustrine deposits. And Takahinata-yama is presumed to have erupted during the age from Pleistocene to Holocene according to Omoto (1964). The terrace plains and alluvial plain were formed by the Arao-gawa and its tributaries.

5 The Kurikoma volcanic area

The volcanic ejecta which form the main bodies of each volcano in the Kurikoma volcanoes are mainly lava. The main bodies of the volcanoes erupted upon the eroded surface of base rocks composed of the Tertiary formation and dacite. This geological feature is shown at the deeply dissected area where ejecta of the volcanoes are highly cliffed. The dacite here is sproadically exposed near the Tamayama strorage dam and along the Sanhazama-gawa. The Tertiary formations are observed along the upper streams of Ichihazama-gawa, Nihazama-gawa and Sanhazama-gawa.

The first eruption of the Kurikoma volcanoes seems to have taken place in the Pleistocene age. The volcanic group consists of Kurikoma-yama the main body of the group, Kokuzō-zan (1405 m.), Ōji-mori (1154.9 m.), Yokone-dake (953.5 m.), Zaru-mori (1355.8 m.) and Eboshi-yama (1161 m.) etc. as parasitic cones. They are built of lava flows and ejecta represented mainly by two pyroxene andesite. The lavas are complicatedly distributed and overlapped, because they erupted repeatedly from these different centers. Some of the good exposures of the lava flows are to be seen at the southwest side of the summit near the upper course of the Osawa. One of the outcrops shows lava which alternately accumulated with dips towards the north at an angle of about 12°, and formed a cliff of about 5 meters in height.

The volcanoes rest upon such base rock as the Tertiary sediments and dacite exposed along the Koshinuke-zawa, Oji-daki (Oji fall), the upper part of the Sanhazama-gawa and near Kurikoma lake (Tamayama storage dam) etc. The specimens of the lava exmained under the microscope are mainly composed of plagiocalase, augite, hypersthene and magnetite etc. The most predominant mineral is plagioclase. Such phenocrystic minerals as plagioclase, augite, hypersthene are abundantly found in the groundmass with a hyalopilitic or pilotaxitic texture.

After the main bodies of the Kurikoma volcanoes were formed, many mudflows rushed down from the volcanic bodies on the lower parts of the volcanoes by agencies of huge explosions. They are the Motozawadake-yama mudflow, Ōji-mori mudflow, Yanagi-zawa mudflow, Dozo-zawa mudflow, Yokone-dake mudflow and Zaru-mori mudflow etc. These mudflows consist of angular rock fragments of two pyroxene andesite of several centimeters to more than 2 meters in diameter, with a matrix of brown volcanic ash.

The Mozoawadake-yama mudflow is seen along the Koshinuke-zawa, Aino-zawa and at the cliffs near Yunokura Spa, etc. This mudflow is supposed to have poured out from the pre-existing crater at the southwestern side of the summit of Kokuzō-zan.

The Ōji-mori mudflow is seen along the O-sawa and in cliffs of the upper stream of the Sanhazama-gawa. The southern end of this mudflow is highly cliffed along the Sanhazama-gawa. This mudflow poured out from the pre-existing crater which was open to the south as a horse-shoe-shaped hollow on the southern slope of the summit of the main body, and overlaps on the Motozawadake-yama mudflow.

The Yanagi-zawa mudflow rushed down from the pre-existing crater which opened semicircularly to the southeast on the south slope of the main body. This mudflow is exposed in the cliffs along the road from Gyosha-daki (Gyosha fall) to the Komano-yu Spa. However, this mudflow is traversed by dacite neck, as is observed on the route between Gyosha-daki and Madono-daki.

The Yokone-dake mudflow poured out from the pre-existing crater which opened semicircularly to the east from the summit of Yokone-dake. It is covered by the Yanagi-zawa mudflow. The mudflow exposed here seems to have run down eastwards, and its terminal is now cut off by the Ubusume-gawa.

The Zaru-mori mudflow rushed down from the pre-existing crater hollowed semicircularly on the northern side of Zaru-mori. The mudoflw is exposed along the Hitotsuishi-zawa and Seikei-zawa.

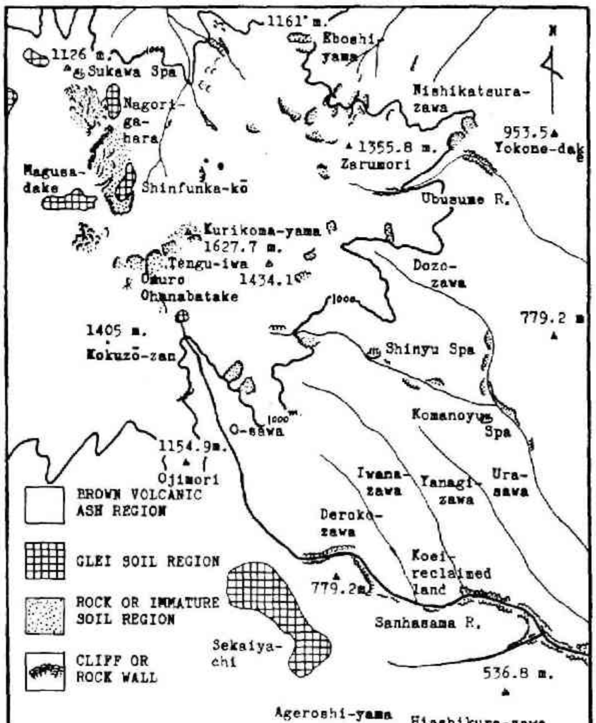

Fig. 9 Distribution of Volcanic Ashes in the Kurikoma Volcanic Area.

6 The Iwate volcanic area

The volcanic products which form the main bodies of each volcano is mainly lava, and alternate accumulations of lava and volcanic fragmental materials. The Iwate volcanic group is underlain by the Tertiary formation, granite and granodiorite. Some of these rest upon such base rocks as the Tertiary sediments, granite and granodiorite exposed along the brooks and rivers. Granite and granodiorite are covered by the Tertiary formation and younger volcanic rocks. The granite, granodiorite and green tuff etc. are sproadically exposed along the Obonai-gawa and Kitakami-gawa. The sandstone and shale exposed along the Kakkonda-gawa near the Takinokami Spa. The outcrops of the Paleozoic group such as quartzite, micaschist and slate etc. are to be seen along the Kitakami-gawa near the eastern part of the Takizawa railroad station, and the foot of Takasaki-yama.

The first eruption which formed the main bodies of the Iwate volcanic area is supposed to have begun from Maru-mori, and to have moved to the west Iwate volcanic group. The east Iwate volcanic group erupted from the eastern end of the west Iwate volcanoes in the last phase of this stage. The west Iwste volcanoes are dissected deeply by the Matsu-kawa, Yakekiri-zawa, Sumi-kawa, Aka-gawa etc. at the northern foot, and Kakkonda-gawa, Shotoku-zawa, Arine-zawa, Yuno-zawa, Mekura-zawa, Omatsukura-zawa, etc. at the southern foot.

The east Iwate volcanoes erupted from the western side of the pre-somma which was connected by Kurokura-yama and Byobu-dake of the west Iwate volcanoes. The east Iwate volcanoes are not so advanced in dissection compared with the west Iwate volcanoes.

The volcanic activities of the southwestern area of the volcanoes probably started with the eruption of Kakkonda volcano, then moved Takakura-yama, Ōshiro-mori, Zaru-mori, Eboshi-yama, Ōmatsukura-yama, Inukura-yama in the order stated based on the kinds of lava and mutual relation of lava flow (Hayakawa, 1951). However, the first eruption which formed the main bodies of the Iwate volcanic area is supposed to have begun from Maru-mori.

The lava of the volcanoes are represented mainly by two pyroxene andesite, olivine two pyroxene andesite, olivine-bearing two pyroxene andesite, monoclinic pyroxene andesite and dacite etc. (Hayakawa, 1951), and forming konides or tholoides.

After the main bodies were formed, many huge explosions occurred, and deposited mudflow materials on the lower parts of the volcanic area. The volcanic land form of the Iwate volcanoes at the present was mainly formed during this stage. The main body of the volcanoes is showing konide shape, however, there is many explosion craters in the volcanic area. At first, an explosion caldera occurred in the Maru-mori area, and formed a somma which includes Kamikura-yama, Nakakura-yama and Shimokura-yama. This somma is represented by a horse-shoe shaped crater wall opened southeastwards. Mudflow materials from here spread toward the northeastern foot. And another large explosion caldera happened between the west Iwate and east Iwate volcanoes, and formed an elliptical crater wall surrounded by Byobu-dake, Yakushi-dake, Onigajō and Kurokura-yama. The volcanic products from here were thrown northwards, and spread to the foot of the volcanoes. There are two atrio lakes in the central part of the elliptical atrio. One is a circular lake called Okama-ko, and the other is a horse-shoe shaped lake called Onawashiro-ko. This kind of volcanic land form seems to be triple volcano.

The east Iwate volcanoes erupted from the eastern side of the west Iwate volcanoes. There is a circular explosion crater called "Ohachi" at the summit, and a central cone called Myokō-zan rises up in this crater. The secondary explosion crater called "Omuro" is deeply hollowed at the southwestern side of Ohachi. This land form seems to be a double volcanoes. The inside of the Omuro explosion crater is eroded by solfataric action, where thickly accumulated ejecta showing various colors such as red, yellow and reddish brown etc. are found.

Amiharari-moto-yu is located at the southern foot of Inukura-yama in the west Iwate volcanic group. Here is also an explosion crater opened semicircular hollow toward the south. Mudflow materials rushed down from here to the south, and accumulated on the Nishi-yama area near the Kakkonda-gawa.

The mudflows in the surrounding area of the volcanoes are classified into the Koiwai mudflow, Aoyama-chō mudflow, Takizawa mudflow and Tairadate mudflow etc. (Mizuno, 1960).

The Koiwai mudflow is the mudflow materials which covered on the Koiwai Farm area. The best outcrop of this mudflow is seen along the Shizukuishi-gawa, and it is composed of the angular fragments of dacite, olivine-bearing two pyroxene andesite etc., large or small, cemented with a yellowish brown ashy matrix. The thickest part of this mudflow is more than 100 meters in the high cliff along the Shizukuishi-gawa near Oireno. Such a mudflow is also seen along the Kurosawa-gawa and Koshimae-zeki etc., but it has some different appearance in the area. The Koiwai mudflow is supposed to have poured out from the Kakkonda volcanic area at the earliest stage of activity. This mudflow is covered by the brown and black volcanic ashes.

The Aoyama-chō mudflow coveres on the area of Mitakega-hara, Makino and Kaigarano etc., and it is composed of the angular fragments of two pyroxene

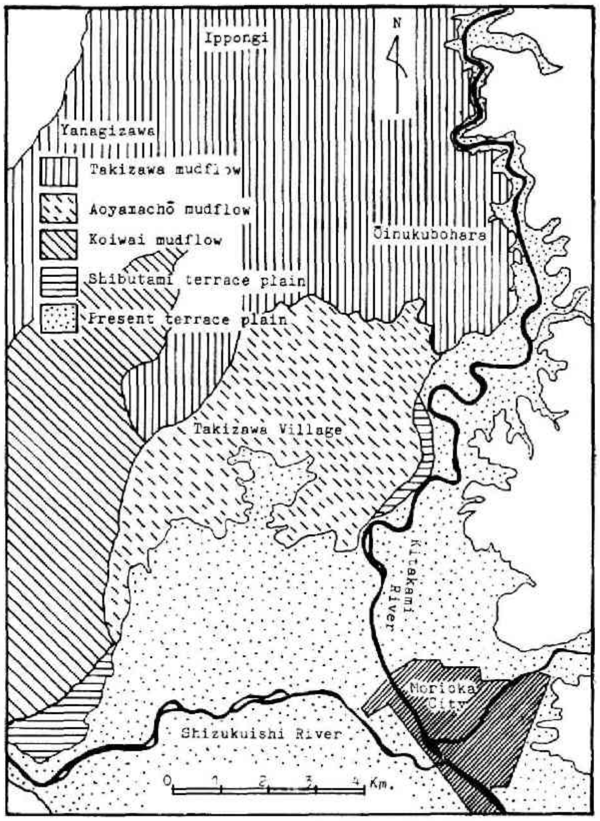

Fig. 10 Geomorphological Map of the Sortheastern Foot of the Iwate Volcanoes.

andesite. This mudflow depsosited about 37 meters in thickness on the alternate bed of coarse sand and sandy clay, and sporadically includes fossil woods in the mudflow materials. This mudflow is covered by the brown and black volcanic ashes.

The Takizawa mudflow spreads widely on the areas of Murasakino and Kagano etc., and it is composed of the angular fragments of dacite and two pyroxene andesite with a yellowish brown ashy matrix. This mudflow exposed along the Kitakami-gawa, and is supposed to have been supplied from the pre-existing crater of the Old-Iwate volcanoes. This mudflow is covered by the brown and black volcanic ashes.

The Tairadate mudflow is supposed to have rushed down from the Maru-mori volcanic area and Ōjigoku-dani explosion crater just beneath at the eastern side of Yakushi-dake, and covers on the area of the Tairadate basin at the northeastern

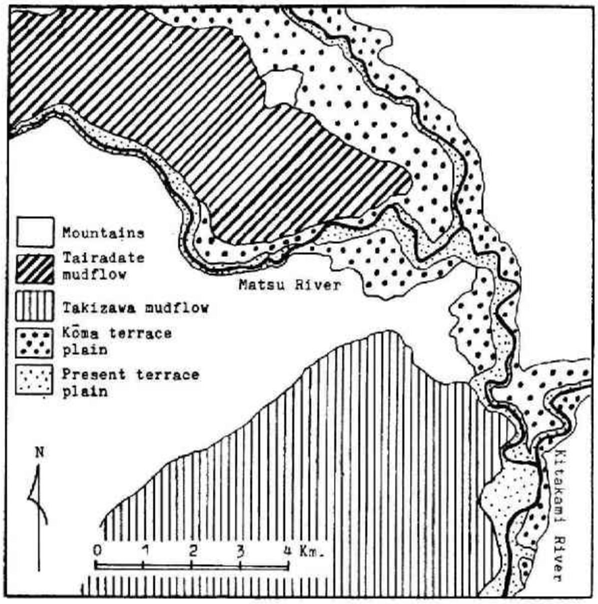

Fig. 11 Geomorphological Map of the Northeastern Foot of the Iwate Volcanoes.

foot of the volcanoes. The mudflow materials are composed of angular fragments of two pyroxene andesite with a brown ashy matrix, and are covered by the brown and black volcanic ashes.

Recent eruption of the lava flow took place later than those mudflows, the brown and black volcanic ashes etc., although it poured out from the northeastern slope near the summit of the east Iwate volcanoes, and extends down to the northeastern foot. This lava flow occurred in 1719, and is the latest volcanic eruption according to the historic records (Meteorological Bureau, 1959).

7 The Yake-yama volcanic area

As already has been stated, Yake-yama as a central cone, and Tsuga-mori and Kuroishi-mori as somma are so remarkably dissected along the explosion crater walls that their structure and geological feature can easily be investigated here and there. One of the good outcrops is to be seen at the dissected valley between Yake-yama and Tsuga-mori where the eastern flank of the central cone was abruptly cut down by the valley, and formed a cliff about 30 meters in height. By the observation, the Yake-yama volcanoes consist of lava and ejecta. These lava and ejecta rest upon the eroded surface of base rocks composed of the Tertiary sediments and welded tuff etc. These geological relations can be seen

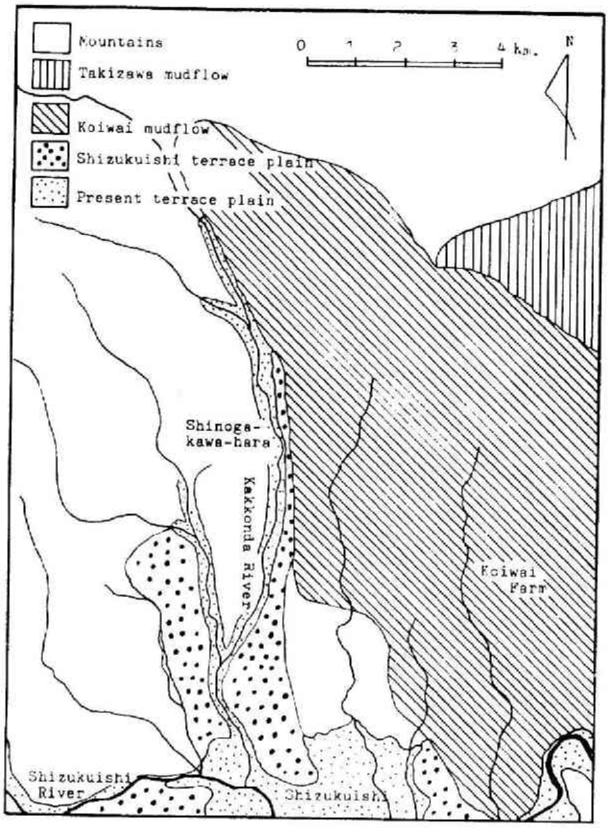

Fig. 12 Geomorphological Map of the Southern Foot of the Iwate Volcanoes.

at the dissected valleys such as Tama-gawa, Shibukuro-zawa, Aka-zawa and Kumazawa-gawa etc

The first eruption which formed the main bodies of the Yake-yama volcanoes is supposed to have begun from Kuroishi-mori and to have moved to Tsuga-mori. Yake-yama as a central cone is supposed to have formed in the last stage. The mudflows in the surrounding areas of the volcanoes were rushed down after the main bodies were formed.

Under the microscope, such phenocrystic minerals as hypersthene, augite, magentite and plaigoclase are found in the specimens of the lava. Especially, major crystals of plaigoclase are abundantly found. It is often characterized by the presence of turbid zone, including minute crystals of augite, hypersthene, magnetite and patches of brown or black glass. The crystals of plaigoclase are respectively 0.8×0.3 millimeters in the maximum size. A noticeable feature of andesitic fragments is the abundance of plagioclase as an enclosure in other minerals and in the groundmass of some specimens.

Rock weathering has progressed deeper and more intensively in the solfatara area. The weathered rocks are showing light color such as white, whitish gray and light gray etc. No crystals of mineral are recognzied in the specimens of the weathered rocks by solfataric action.

8 The Hachiman-tai volcanic area

The Hachiman-tai volcanoes range in size from large hills to great mountains, but main bodies of the volcanoes are characteristically cone-shaped. The volcanoes under consideration rise up on the foundation composed of the Tertiary formation, older andesite and welded tuff etc. The volcanic bodies are constructed by lava of two pyroxene andesite, brown volcanic ash layer and various kinds of ejecta etc. Some of these volcanic products are alternately piled up, starting mostly with the eruption of agglomerate and lava. Such a structure is commonly seen at the dissected areas as well as along the upper course of the Aka-gawa. After the eruption of lava, the brown volcanic ash thickly accumulated on the lava, and a shield shape of the volcanic body was formed.

There are more than ten craters in this volcanic area. They are respectively found in the area. The location of pre-existing crater is, however, inferable from the structure and topography of these volcanoes, although the original topographical feature was largely destroyed later by explosions and dislocations. Several pre-existing craters are found in the area. One of remarkable pre-existing craters is preserved in the area of the Tōshichi Spa, where the mudflow poured out at the last stage of activity and rushed down eastwards along the Kitano-mata-zawa. The pre-existing crater here is semicircularly surrounded by a steep wall on the southeastern flank of the summit of Hachiman-tai. It opens eastwards, and its bottom is filled up with an accumulation of mudflow. The underlatory surface of this mudflow is thickly covered by a forest of beech and is adorned with swamps.

There is also a similar pre-existing crater on the northeastern flank of the summit of Hachiman-tai. It opens northwards, and its bottom is filled up with mudflow material. This mudflow material begins to be exposed on the northeastern flank of the summit of Hachiman-tai, and spreads extensively down to the Appi-gawa, Chie-zawa and their tributaries. Angular or subangular fragments of two pyroxene andesite with a matrix of brown volcanic ash are the mudflow material in this area. Although these two pyroxene andesite fragments indicate somewhat different features from place to place, most of them are compact and remarkably porphyritic. They have a dark gray or blackish gray color.

In connection with it, two pre-existing craters are located on the flank of Chausu-dake. One of them is found on the northern flank of Chausu-dake, and opened horse-shoe-shaped hollow towards the south direction. The largest one is scooped out downwards from the eastern flank of Chausu-dake.

The extensive distribution of lavas and ejecta suggests that there was once an important active center in the Hachiman-tai area. It is supposed to have been repeated several times, resulting in the formation of such remarkable peaks as the summit of Hachiman-tai, Chausu-dake, Mokko-dake, Genta-mori, Maemori-yama and Appi-dake.

9 The Hakkôda volcanic area

Following Cotton (1944), the types of volcanoes are classified into four types, such as basalt cones, and composite or strato-volcanoes. This classification is based largely upon whether the volcanic pile was built up as the result of the outpouring of fluid or effusive lavas, as the product chiefly of ejected pyroclastic materials, or by a combination of the two.

The main bodies of each volcano in the Hakkōda volcanoes exhibit rough stratification produced by alternating sheets of lava and pyroclastic material. Its structure attests to alternating periods of explosive and quiet eruption. A cinder cone around a explosion crater of O-take is consisted with an encircling ring of pyroclastic debris consisting of ash, lapilli, and coarse materials.

These lava and pyroclastic material, and also welded tuff, etc. are underlain by the Tertiary formations such as the Tsubokawa formation, Shibamori-yama rhyolite and Shimoyu formation (Miyagi et al, 1967). These geological relations can be seen at the dissected cliffs along the upper sream of the Ara-kawa and Komagome-gawa, and also at the Kamikita Mine and Kuro-mori.

The first eruption which covered the Tertiary formations is supposed to have begun from welded tuff in the surrounding areas of the volcanoes (Minato and Ijiri, 1958), and to have moved to the somma. Shibamori-yama, Nanajumori-yama, Ishikura-yama and Mae-dake, etc. range semicircularly as somma.

After these activities, the central cone group of the volcanoes have been constructed. Namely, Akakura-dake, Ō-take, Takada-ō-take of the north Hakkōda volcanoes, and Yoko-dake of the south Hakkōda volcanoes, as central cone group, rose up after the somma formed. The central cones are characterized by the frequency of explosion craters, large or small. The present topographical feature of the volcanoes is considerably affected. They are found near the summits of Akakura- dake, Ido-dake, Ō-take and Iō-dake etc. These explosion craters were formed at the last stage of activity, and rushed down mudflow material from the crater to the lower parts.

One of remarkable explosion craters is preserved on the northern flank of Akakura-dake. The explosion crater here is a horse-shoe-shaped hollow which is surrounded by a high cliff of about 200 meters high above its bottom. Its diameter is about 1000 meters from southwest to northeast, and about 600 meters from north to south. It opens northeastwards, and its bottom is filled up with an accumulation of mudflow material. There is also similar explosion crater on the summit of Ido-dake. This explosion crater is circularly surrounded by cliffed wall of about 80 meters high, and about 500 meters in diameter.

Jigoku-numa of Sukayu in the southwestern foot of Ō-take, and and Suiren-numa in the southeastern foot of Ishikura-dake, seem to like explosion crater lakes. Also, there are atrio and atrio-lakes in the volcanic area. One of them is in Tashirodaira.

About 24 areas of landslide can be seen at the southwestern foot of Ō-take. However, the material which was rushed down, looks like a debris-flow. This material consists of numerous larger or smaller rock fragments, lapilli, sands and ashes, and show gray or whitish gray color. The size of rock fragments is several centimeters to 1 meter, and sometimes more than 2 meters in diameter. The rock fragments are angular or subangular. Debris deposition was in the form of long, relatively narrow strips extending radially from apex toward margin. The average width of the flows is 20 to 50 meters. And the average length of the flows is 100 to 800 meters. Depth of debris deposited by the flows decreases downslope from fan apexes. Thickness of the deposits of the rock fragments in the middle parts is 2 to 10 meters, and the material left in the mudflow-like deposits on fan margins is thinner still, one meter or less on the average.

These areas in which the landslides are occurred, consist essentially of lava, alternating beds of lava and pyroclastic materials, and are covered by loose and coarse masses of pyroclastic debris consisting of ash, lapilli and rock fragments. Also, there are very few growing plants. Slopes tend to be rugged, with exposures and steep inclination. Winters are much snow, summers and autumns are generally heavy rain on the western flanks of the mountains. Temperatures in wintertime are invariably below zero.

The topographical characteristics on the western flanks of Ō-take make it especially appropriate for the study of landslide formation. Steep slopes, sparse vegetation cover, and a climate in which summer thunderstorms and winter snowfalls are experienced all appear to favor landslide development.

When the snow is melted in spring, or heavy rains attacked to the western flnaks, the surface materials in this area are flowed down by streams coming from the upper areas.

The mechanism of the landsldie formation and debris material, is similar to the origin of alluvial fans in the White Mountains area in southeastern California and western Nevada (Beaty, 1963), and also to the formation of mudflows in semiarid mountains (Sharp and Nobles, 1953) (Blackwelder, 1928).

III Stages of deposition of the volcanic ashes

1 The Bandai volcanic area

The stages of the deposition of the volcanic ashes which erupted from the Bandai and Necome volcanoes on the surface of the earth are divided into two stages judged from circumstances of deposition of the volcanic ashes or degree of weathering of the volcanic ashes, etc. These two stages are, (a) The first stage – This stage is the period of deposition of the B-series volcanic ash (brown soil color) on the volcanoes and the vicinity. (b) The second stage – This stage is the period of deposition of the A-series volcanic ash (black or dark brown soil color). The stages of deposition of the volcanic ashes are described in more detail as follows.

(1) The first stage

This stage is the period of deposition of the B-series volcanic ash on the Bandai and Necoma volcanic areas. The B-series volcanic ash was deposited by the volcanic activities of the Bandai and Necoma volcanoes. The B-series volcanic ash after being erupted was changed into a brown volcanic ash by weathering and oxidation of the iron in particles of the ash. Namely, the color of the B-series volcanic ash was changed into a brown color. At present, the soil color of the B-series volcanic ash is indicated mainly in 7.5 YR 4/6–7/6 of the standard soil color chart.

The B-series volcanic ash which was deposited widely on the Bandai and Necoma volcanic areas is subjacent to the A-series volcanic ash in this volcanic area. The distribution of the B-series volcanic ash is wide spread and accumulated to 0–2 meters in thickness.

(2) The second stage

This stage is the period of deposition of the A-series volcanic ash on the B-series volcanic ash layer in this area. This A-series volcanic ash was deposited at an age younger than that of the period of the B-series volcanic ash. The A-series volcanic ash is accumulated to 0–80 centimeters in thickness. The soil color of the A-series volcanic ash is black or dark brown, and is indicated mainly in 7.5 YR 2/1–7.5 YR2/2 of the standard soil color chart. This ash is may be blown off from Bandai-san when exploded in 806 and in 1888.

Historic records of volcanic activities are not so confided in details. However, historic records are helpful to know the volcanic land formes, distinction and distribution of the volcanic ashes, etc. in the rough. Then, some short descriptions are described here.

The number of volcanic activities that occurred in the Bandai volcanic area since its first eruption is unknown. The historic records compiled by the Meteorological Bureau show that volcanic activities took place twice extensively, and several times on a small scale. The large activities which remarkably influenced the volcanic land form occurred in 806 and 1888.

(a) The activity in 806, according to the historic record, Bandai-san exploded, and produced a large quantity of sulphur distributed about 40 kilometers around the volcanoes. Many persons were injured by the sulphuric gas. At this time, Lake Inawashiro was formed and thus the issuing of sulphuric gas ceased. More than 50 villages such as Tsukiwano-sato and Sarashinano-sato etc., were drowned by Lake Inawashiro. (Lake Inawashiro may have been formed as a dammed lake or a caldera lake by this activity).

(b) On July 15, 1888, at 7 a.m., a rumbling noise originated at Bandai-san, and strong earthquakes occurred at 7.30 a.m., and their shock continued. At 7.45 a.m., Shō-bandai-san suddnely exploded accompanied with a still stronger earthquake and a terrific noise. At this time, the explosions occurred 15–20 times per minute, and more than half of the mountain body of Shō-bandai-san was blown off. The volcanic gas was thrown up to about 640 meters in height, and the detonation was heard within about 50 kilometers on the windward side, and to the Pacific Coast which is approximately 100 kilometers distant from Bandai-san on the leeward side or northeast direction. The noise was heard as far as Takai County in Nagano Prefecture, and to Takada City and Sadogashima in Niigata Prefecture. The volcanic earthquake shake was felt within a radius of about 50 kilometers from Bandai-san. The volcanic ash rising up into the air was drifted southeastwards to the Pacific Coast, and accumulated in the area of a radius of about 70 kilometers. The explosion crater opened in U-shape toward the north, and a great mudflow rushed down at the speed of 45–77 kilometers per hour in the area of about 2.2 kilometers in east to west direction, and about 2 kilometers in south to north direction. The mudflow materials buried 7 villages at the mountain foot, and killed 461 persons, injured 70 persons, and destroyed 110 houses. The damaged area was 7.1×10^7 square meters. After the explosion, the area was shaken severely for 30–40 minutes.

(c) On July 5, 1897, at 10.20 a.m., this area was shaken with rumbly noises, that continued repeatedly 11 times till the evening on 8th.

(d) Landslides occurred at the eastern side of the U-shaped explosion crater wall on the 9th and 15th of May, 1938. The damaged area was more than 2.3×10^5 square meters. On the 9th, muddy soil flowed down to the Kawakami Spa area, and killed 2 persons, injured 4 persons and destroyed 4 houses.

(e) Landslides occurred three times at the explosion crater wall of the northern side of Bandai-san on the 3rd, 6th and 7th of April, 1954.

(f) From the 1st to 5th of July, 1954, earthquakes occurred frequently. The Inawashiro Meteorological Station recorded earthquakes on a seismometer, once on the 1st, nine times on the 2nd and on the 5th.

In connection with the volcanic activity in 1888, several fumaroles opened on the atrio just beneath the explosion crater wall.

As state before, volcanic ashes in the Bandai and Necoma volcanic areas are classified into two main volcanic ashes based upon the soil colors. One of them is the A-series volcanic ash (mainly Brown 7.5YR4/3–Light brown 7.5YR5/6).

Generally speaking, volcanic ashes which were deposited primarily by volcanic activity, winds and wind direction etc., are also removed secondarily by agencies of winds and running water etc.

The B-series volcanic ash is underlain by lava and mudflow material, and is widely spread and accumulated to 0–2 meters in thickness in this area. Sometimes, a brown volcanic ash is deposited with mudflow materials as a matrix. A dark red or dark brown colored volcanic ash as a matrix of mudflow materials was also deposited in the area of the northern side of Bandai-san, especially in the vicinity of the Goshiki-numa Lake group.

On the other hand, the A-series volcanic ash had been deposited to a thickness of 0–80 centimeters in the area south of Bandai-san and Necoma-yama. However, the A-series volcanic ash is only slightly accumulated or absent in the area north of Bandai-san. It is probable that the A-series volcanic ash was blown off by the explosion at the gas blast in 1888.

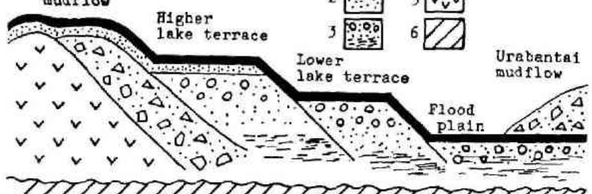

Fig. 13 Relationships between the Volcanic Ashes and Topographical Surface in the Bandai Volcanic Area.
1:Black volcanic ash (A-series volcanic ash). 2:Brown volcanic ash (B-series volcanic ash). 3:Terrace material, 4:Mudflow material, 5:Volcanic body, 6:Bedrock

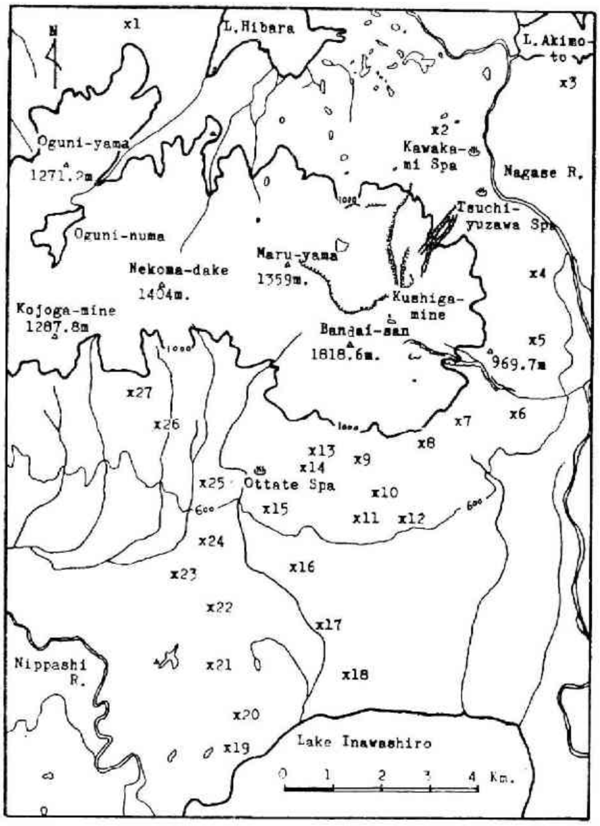

Fig. 14 Localities of the Columnar Sections in the Bandai Volacnic Area.

The round gravel layer with a fine volcanic ash material is mainly distributed along the present rivers. However, the A-series and B-series volcanic ashes are not accumulated on the present river terrace. The origin of the river deposits is thought to be heavy rainfalls or snow avalanches.

2 The Zaō volcanic area

There are two principal types of volcanic activity: explosive eruptions and queit flows of lava. An explosive eruption of this sort throws up quantities of fragmental material, including pulverized pieces of rock from the solid cone or from the base of the volcano, and bits of chilled magma.

Finer, dust size particles are called ash. And fresh ash generally shows black or gray system soil color when deposited on the ground by volcanic explosions.

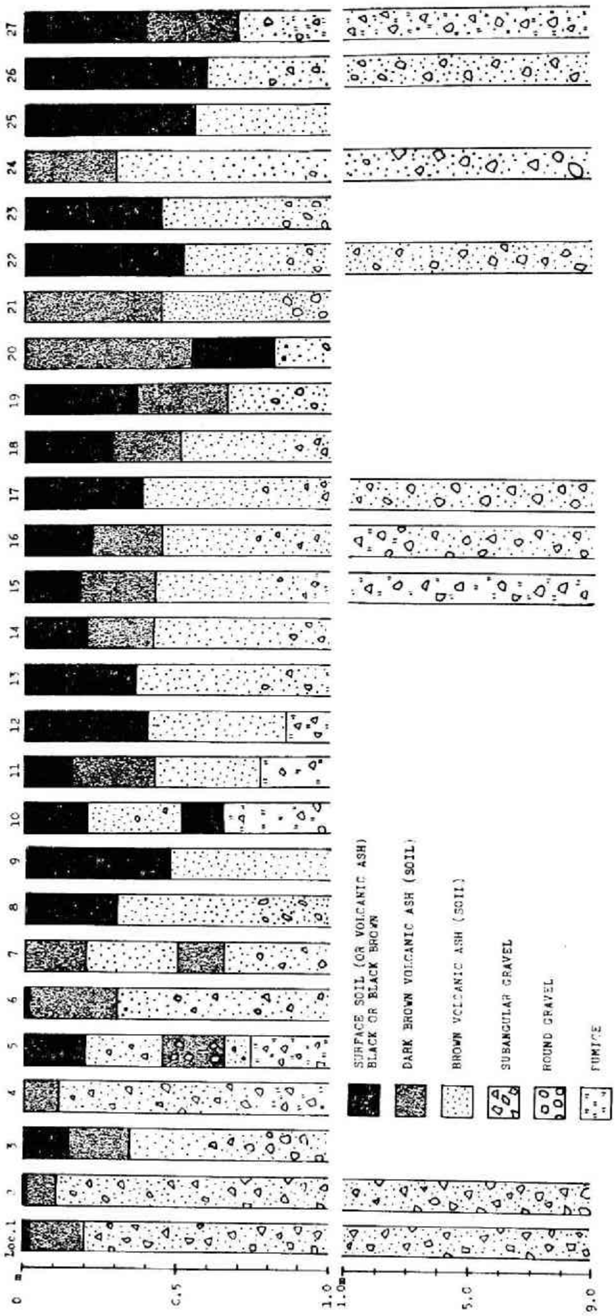

Fig. 15 Columnar Sections in the Bandai Volcanic Area.

When fine ash is blown into the upper atmosphere, it may remain there for long period.

The stage of the deposition of the volcanic ashes which erupted from the Zaō volcanoes on the ground surface are divided into two stages judged from the soil colors, circumstances of deposition of the volcanic ashes and degree of weathering of the volcanic ashes, etc.

These two stages are (1) The first stage – This stage is the period of deposition of the B-series volcanic ash (mainly brown color) on the volcanoes and their vicinities, (2) The second stage – This stage is the period of deposition of the A-series volcanic ash (black or blackish brown color) on the B-series volcanic ash layer.

Volcanic ashes which were deposited primarily by the influence of circumstances when explosions occurred, namely winds and wind direction etc., can also be removed secondarily by agencies of wind action and running water etc. In the mechanism of the removal of the topsoil from the land, the process is severer in a sharp slope geomorphologically. Also volcanic ash can be removed from the lower part to the upper part by the wind action, and thus the volcanic ash layer become disordered in limited areas by the result of repeated erosion and deposition by wind action and or running water (Murayama, 1964).

The B-series volcanic ash is underlain by lava, lapilli and volcanic sand in the environs of the Zaō volcanoes. As already mentioned, the distribution of the B-series volcanic ash is wide spread and accumulated to 0–20 meters in thickness. It has a parting layer of black volcanic ash in the B-series volcanic ash layer, and or covered by the A-series volcanic ash in a limited area. Such a parting layer of the black volcanic ash is caused by the disorder of the ash layers by wind action or running water, but there are frequent occasions, the phenomenon of the parting layers where it may be due to the disparity of leaching or products of ferric oxide depending upon the particle size of the volcanic ashes. For instance, a parting layer of the black volcanic ash in the B-series volcanic ash layer at the area of Nanokahara, Shimizuhara is shown to be composed of grains as large as sands. Namely, the result of mechanical analysis by the ASK elutriation in grain size is shown as coarse sand, 65.0 percent; fine sand, 19.2 percent; silt, 7.6 percent; clay, 8.2 percent in the A-series volcanic ash of the upper layer, and coarse sand, 25.2 percent; fine sand, 42.5 percent; silt, 6.5 percent; clay, 25.8 percent in the B-series volcanic ash layer which underlies the surface layer of the A-series volcanic ash, but coarse sand, 80.2 percent; fine sand, 9.4 percent; silt, 4.1 percent; clay, 6.3 percent in the parting layer of the black volcanic ash. Namely, coarse sand is abundant and clay is little in the A-series volcanic ash, on the contrary much clay and a small quantity of coarse sand composes the B-series volcanic ash.

Hence, the disparity of leaching depends upon the grain size and this is presumed to relate closely to the soil color. Such parting layer of the black volcanic ash in the B-series volcanic ash layer is distributed in the areas where the A-series volcanic ash is deposited on the surface of the earth. Especially, the parting layer is 5 to 60 centimeters in thickness in the areas of Nanokahara, Togatta, Simizuhara and Aone etc. This black parting layer is supposed to be formed as the result of unprogressive leaching of the particles, and by the not so advanced oxidation of iron in the particles of volcanic ash because of the large grain size. It is thought that the black parting layer was deposited under a natural environment of cold climate, and this may explain the unprogressed leaching.

The upper brown ash which was deposited on the black parting layer is correlated to the B-series volcanic ash which yeilded the remains of pottery with a pinnate pattern in the last stage of the Jōmon culture era. This B-series volcanic ash layer may have been deposited during the Atlantic or Sub-boreal period. Also, the lower brown ash which was deposited under the black parting layer is correlated to the Nagano volcanic ash layer. Therefore, the writer supposes that the black parting layer was deposited in the Preboreal or Boreal period. Therefore, the parting layer shows a black soil color in the B-series volcanic ash layer. Also, the area in which is distributed the black parting layer correspond to the area which is covered by the A-series volcanic ash on the surface of the earth. From such observation, the A-series volcanic ash and the black parting layer are thought to have been blown off the same source during volcanic activities.

Lapilli and grayish white volcanic sand are accumulated remarkably in the area within the limits of about 4 kilometers east of Okama, the same ejecta accumulated in a rather wide area from the southern foot to the western foot of Katta-dake, and on Kumano-dake and its vicinity.

Goshiki-dake is built up of such ejecta as agglomerate, lapilli, sand and ash which are well stratified and show varying colors. Of these rocks, the agglomerate is exposed in the northern cliff as well as at its opposite side. It is only 1 meter or thereabouts of two pyroxene andesite, 1–15 centimeters in diameter. There are two kinds of these fragments. One is black and of compact andesite, whereas the other is a scoriaceous variety with the same color. Both have a porphyritic texture. Sand and ash are the most outstanding ejecta of this area, being well exposed in the cliff and the summit. They consist of plagioclase, augite, hypersthene, magnetite as well as of tuffaceous substances and minute fragments of two pyroxene andesite.

Recent ejecta are widely accumulated on the surface of Goshiki-dake as a central cone and its surrounding area. The occurrence of such ejecta can easily be recognized at a distance, because of the white or gray color similar to that of the intensely altered O-sawa lava. They are composed of ash and lapilli. The latter is represented by angular fragments of two pyroxene andesite, commonly from 0.5 centimeters to 5 centimeters in diameter. Most of these fragments have a light gray color, but there are frequently porous or compact andesites with a dark gray or gray color. Light gray or gray colored fragments have been intensely subjected to the solfataric action and are represented by opalized andesite. This fact suggests that some of these have undoubtedly been torn off from the altered O-sawa lava by the explosion of this central cone.

Through the phenomenon of the alternating beds of sand and ash in the surrounding area within the limits of about 1 kilometer from Okama and in the area for a distance of about 3 kilometers eastward, these sands and ashes are thought to have been exploded off and deposited under the conditions of high temperature during volcanic activities.

The stage of deposition of the volcanic ashes are described in more detail as follows.

(1) The first stage

This stage is the period of deposition of the B-series volcanic ash (brown color) on the lavas and mudflow materials in the Zaō volcanic areas. The B-series volcanic ash was deposited by the volcanic activities of Aoso volcano, and by the south and north Zaō volcanoes. The volcanic ashes by weathering and oxidation of the iron in particles of the ash. Namely, the color of the volcanic ashes was changed into a brown color. At present, the soil color of the B-series volcanic ash is indicated mainly in Brown 10YR4/6 of the standard soil color chart.

The concept that laterite and bauxite were the end product of weathering arose from the abundant occurrence of rocks in the humid tropical regions. In general the laterites are granular, porous, and have low water-holding capacity. They are capable of being tilled immediately after heavy rains but are subject to drought. Being highly leached, they are low in plant foods, both mineral and organic, and are not capable of sustained cropping without heavy fertilization. Most of them have red or brown A-horizons and deep B-horizons of dark red color. Such as are weathered from rocks high in iron are composed largely of iron oxide, and some are suitable for use as iron ore. The lower horizons of the laterites derived from them are buff or gray in color and consist largely of the hydrous oxides of aluminum. Oxidation in the process of weathering usually occurs by the combination of elemental oxygen with the weathering substance. The brown volcanic ash is a kind of end product of weathering from fresh volcanic ashes.

The B-series volcanic ash which was deposited widely on the Zaō volcanoes and their vicinities is subjacent to black volcanic ash in the area from the southern side of the Akiyama-zawa to the Kawasaki Town area. Some remains of Jōmon culture pottery (straw-rope pattern pottery) of prehistoric age and charcoal of a blazing fire supposed to be of prehistoric age were found by the writer from the upper layer of the B-series volcanic ash about 10 centimeters below the boundary of the A-series volcanic ash at the edge of the Nanokahara fan. Also, some remains of Jōmon culture pottery of prehistoric age were found on the surface of the B-series volcanic ash at places eroded by the agency of wind at the Fubō colony and Suzuri-ishi colony at the southeastern foot of the south Zaō volcanoes. Almost all of the remains which were found in this area have a pinnate pattern which characterize the last stage of the Jōmon culture era.

In judgement of such a fact, the upper layer of the B-series volcanic ash was deposited by the volcanic activities during the last stage of the Jōmon culture era (the last stage of straw-rope pattern pottery culture). And, a large quantity of the volcanic ash erupted from the south and north Zaō volcanoes, to be deposited widely in the Zaō area during the same stage.

The B-series volcanic ash which includes these remains of Jōmon culture pottery is assigned to the upper part of the Nagano volcanic ash layer which veiled the Nagano terrace plain as the second terrace plain of the Matsu-kawa drainage area. A typical locality showing the sequence of the Nagano volcanic ash layer (Tayama, 1933) is at Nagano, Zaō Town, Miyagi Prefecture, where it has accumulated to about 2.5 meters in thickness. The brown volcanic ash which carries many small angular gravels erupted from the crater of Numa just beneath the southern foot of Mae-eboshi-dake is a correlative of the Nagano volcanic ash layer. The Nagano volcanic ash layer is correlated to the Tachikawa loam of the Kantō district by Nakagawa etc. (1960). However, the B-series volcanic ash which is correlated to the Nagonao volcanic ash is supposed to be a deposit of a newer or younger age than the Tachikawa loam as is judged from the occurrence of the Jōmon pottery. And, the Nagano volcanic ash layer is considered by Furuya (1965) to have erupted in the north Zaō volcanoes. But, at present, there are no certain materials by which the actual source of eruption can be determined. However, it can be stated that the remains of Jōmon culture pottery with a pinnate pattern were found from the B-series volcanic ash at the foot of Fubō-zan, the south Zaō, and there is no distinction between the B-series volcanic ash of the north and of the south Zao volcanoes so far as determined by the method of heavy mineral analysis or other experiments.

Generally speaking, so far as concerned with aeolian erosion many fields on the eastern foot of the Zaō volcanoes lost several centimeters of topsoil during a year. The field surface which had been cultivated for several years developed a gentle concavity between the windbreaks as a result of soil erosion. However, the B-series volcanic ash layer covered with the A-series volcanic ash is not blown off by high winds because of being resistant to winds.

(2) The second stage

This stage is the period of A-series volcanic ash (black color) that originated from the explosion crater named "Okama", and was deposited in the area eastwards of Okama. This A-series volcanic ash was deposited at an age younger than that of the period of the B-series volcanic ash. The A-series volcanic ash is not so advanced in the stage of clay which resists from weathering and leaching. A boundary line of the layer is shown clearly between the A-series and B-series volcanic ashes. Such a black volcanic ash is found on the surface of the earth of the Onikōbe and Narugo volcanoes in the region north of the Zaō volcanoes, or in the vicinity of the Azuma, Bandai volcanoes in the region south of the Zaō volcanoes.

In Kyushu in the southern part of Japan, a black volcanic ash erupted from each central cone, by the volcanic activities, of Aso-zan, Kurishima-yama, Sakura-jima, Kaimon-dake, Unzen-dake, Kuju-zan, Tsurumi etc., and this ash was deposited as a Bora bed (pumice bed) or a Kora bed (chart pan of lapilli and volcanic sand). The boundary of the beds is shown clearly. It is interesting and remarkable that this black volcanic ash has yielded ceramics of the Jōmon, Yayoi and latter cultures, all of prehistorical age, by which the chronological division of the ash layers may be classified (Gohara, 1963) (The Kantō Laom Research Group, 1965). However, the A-series volcanic ash layer of the Zaō volcanoes do not contain such ceramics, and no distinction is obviously shown between each bed by the characteristics of the ashes. So, it is difficult to classify the A-series volcanic ash in the Zaō area chronologically. The A-series volcanic ash layer underlain by the upper layer of the B-series volcanic ash which contains the remains of Jōmon culture was mainly deposited since the volcanic activities of the last stage of the Jōmon culture in the Zaō area. The number of times of volcanic activity is unknown in the Zaō volcanoes since its first eruption. This may be also said of the volcanic activities in historic time, because of the insufficient data. However, the quantity of the ashes during historic time must depend upon the historic records of volcanic activity. The historic records are not so confided in details. The direction of deposition of the A-series volcanic ash is towards the east in fan-shape, and it spread within a distance of about 20 kilometers from the explosion crater "Okama" to the Kawasaki Town area. The volcanic ejecta are lapilli, volcanic sand, scoria and pumice layer etc., within the limits of about 1 kilometer from "Okama" towards the east area and the Sainokawara area. The A-series volcanic ash accumulated eastwards of the eastern edge of Sainokawara. The fan-shaped distribution of the volcanic ashes towards the east is thought to be due to the westerly wind and monsoon when the ejecta exploded. The season of the small volcanic activities which accumulated volcanic ashes at the foot was mainly during the winter season accurding to the historic records. So far as is shown by the records compiled by Mihara (R. Mihara, 1955), volcanic eruptions occurred in 773, 1227 (September), 1230 (Novermber 8), 1334, 1350, 1623 (April 16), 1624 (October 5), 1630, 1669, 1670 (March 7), 1964 (May 6), 1794 (August 29), 1796 (February 16), 1804 (April), 1809 (November 23), 1820 (December), 1921 (March 29), 1830, 1931 (October 19), 1867 (September 24), 1894 (March), 1895 (February 15, 19, March 22, September 27), 1896 (March 8), 1897 (January), 1906, 1918 (January-August), 1927 and 1939.

(a) On September, 1227, according to the Hōjō-kyūdai-ki, a large amount of lapilli was blown off like a sprinkling rain eastwards to Shibata-gun, Matsuno-kuni, where many men and horses were struck and injured by the falling stones. The size of the falling stones is as large as the fruit of citron, but a little bit longer.

(b) On October 26, 1230, according to the Azuma-kagami, a large amount of lapilli was blown off and fallen down like a sprinkling rain eastwards to Shibata-gun, Matsuno-kuni. Some of falling stones were presented to the Shōgun's house. The size of stones is as large as the fruit of citron.

(c) The explosion took place on April 16, 1623, according to the Teizankō-jika-kiroku (The Date clan record).

(d) The volcanic activity on October 5, 1624, seems to have started with a rumbling noise that continued day and night. The lapilli were fallen down like rain fall, also large stones were blown off, it caused a serious damage to farms, according to the Teizankō-jika-kiroku.

According to a local tradition, great quantities of volcanic ashes accumulated eastwards in Katta-gun, Shibata-gun and Natori-gun in Miyagi Prefecture.

(e) In 1630, the explosion took place with a rumbling noise, according to the Katta-gun chronological table.

(f) In 1670, a large quantity of volcanic ashes was blown off and accumulated in the areas of Katta-gun, Shibata-gun and Natori-gun, where it caused interruption of farming. This description is according to the Katta-gun chronological table.

(g) The Zaō shrine on Katta-dake was fired by the minor volcanic activity on the 6th of May, 1694, according to the Date clan record.

h) Nine minor explosion holes were formed in the southestern area of the explostion crater "Okama" by the activity on 29th of August, 1794, according to

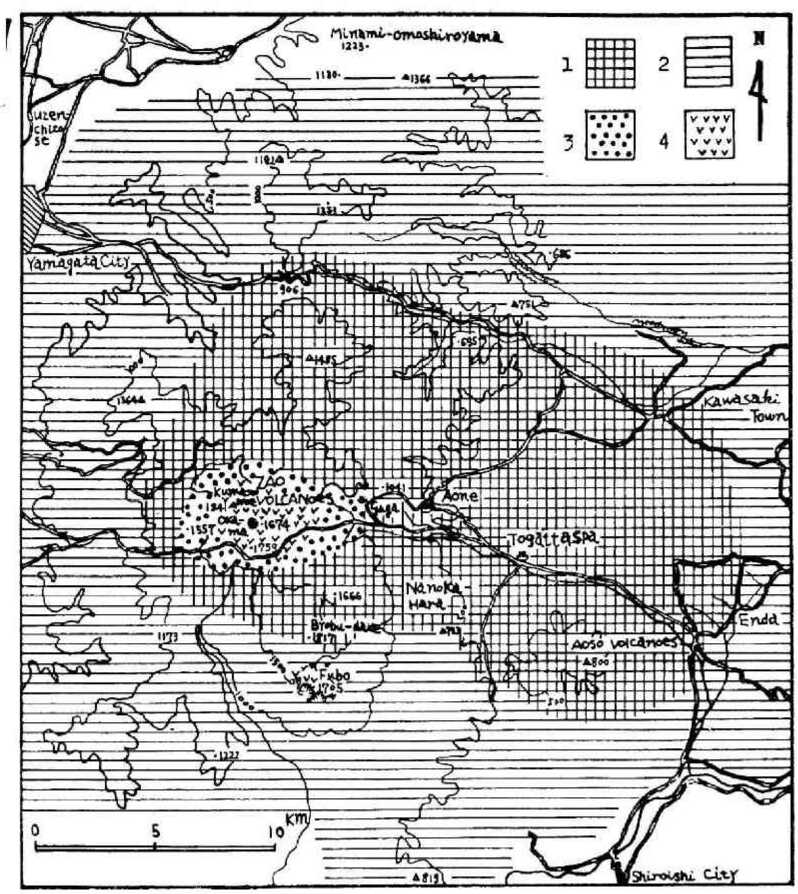

Fig. 16 Distribution of Volcanic Ejecta in the Zaô Volcanic Area.
1: Black volcanic ash, 2: Brown volcanic ash, 3: Volcanic sand, 4: Rock land

the Katta-gun chronological table.

(i) When the explosion occurred on November 23, 1809, muddy water flowed out from Okama, and down to the Abukuma-gawa where almost all of the fishes were killed by the poisonous water, according to the Shōzankō-jika-kiroku (The Date clan record).

(j) On December 1820, water began to boil by the activity in Okama, and the river rose more than 6 meters, according to the description by Yujirō Kikuchi.

(k) Zaō-dake exploded on October 19, 1831, according to the Ryuzankō-jika-kiroku.

(l) An unexpected inundation due to the overflow of muddy water from

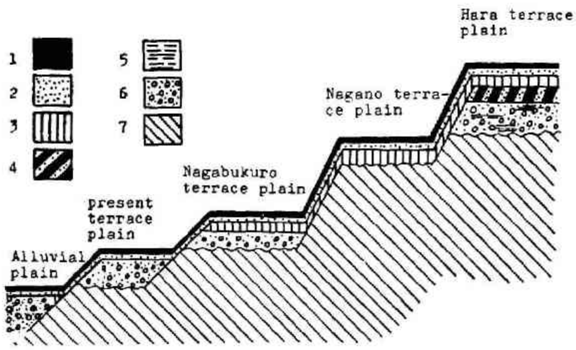

Fig. 17 Relationships between the Volcanic Ashes and Terrace Plain at the Eastern Foot of the Zaô Volcanoes.
1: Black volcanic ash (Okama volcani ash), 2: Brown volcanic ssh, 3: Nagano volcanic ash, 4: Hirasawa volcanic ash, 5: Clay, 6: Gravel and sand, 7: Bedrock

Okama occurred along the Nigori-gawa and killed three men who had stayed there to take a bath in the hot spring near the eastern foot of Goshiki-dake, also the river rose more than 6 meters, on September 24, 1867, according to the description by Yujirō Kikuchi.

(m) According to the description by Yujirō Kikuchi, on February 15th 1895, the mission of white smoke rose up soon after a rumbling noise took place. It was 9.30 in the morning, and the weather was exceedingly fine. The water of Okama rose up and sulfuric water was blown off, the poisonous water overflowed from Okama rushed down along the Matsu-kawa and Shiroishi-gawa, where many fishes were killed.

On 19th of the same month as above, a rumbling noise took place again at Okama, and the running water rose up at the Shiroishi-gawa.

On 22nd of March, a rumbling noise occurred at Okama, and sulfuric water rose up at Shiroishi-gawa.

On 27th of September, Okama broke out by a remarkable explosion soon after a rumbling noise took place. In this volcanic activity, lapilli, scoria and volcanic ash were abundantly blown off northeastwards.

(n) The most recent activity is represented by that which took place in 1939. The water of Okama presented an extraordinary sight in July, the green colored water here was first mottled with many white spots due to the presence of innumerable sulfur grains which came up from the bottom. These grains had a hollow structure and measured 1 millimeter or thereabouts in diameter.

In connection with this volcanic activity, several fumaroles opened on the slope situated at about 1.5 kilometers northeast of Okama.

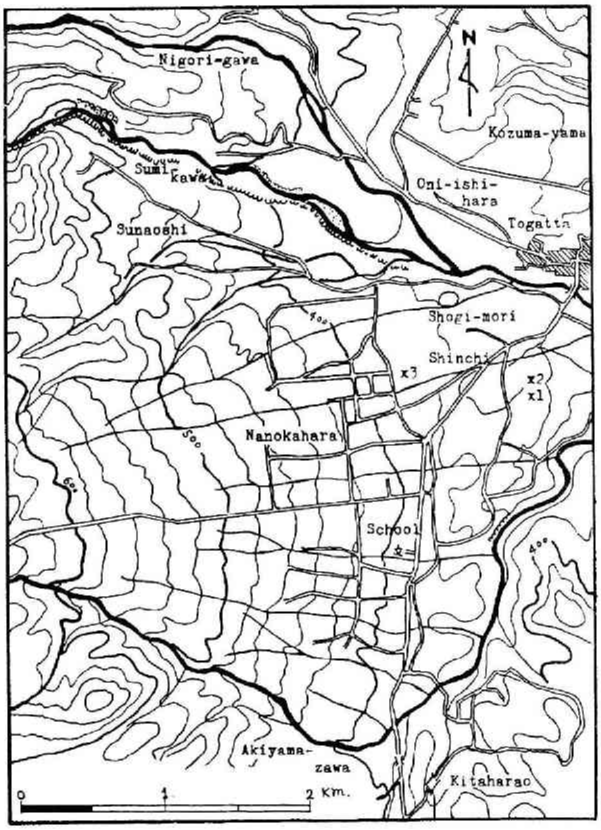

Fig. 18 Localities of Archeological Materials in the Vicinity of Nanokahara. (x: Locality)

As mentioned above, the A-series volcanic ash which was deposited on the surface at the foot was supposed to have accumulated since the last stage of the Jōmon culture, but mainly during historic time. As to know through the historic records, the A-series volcanic ash was blown off and accumulated from Okama. So, the writer calls "the Okama volcanic ash" (1960) for the A-series volcanic ash which was deposited on the surface at the foot. This A-series volcanic ash is loose and accumulated to 0–1.5 meters in thickness above the B-series volcanic ash. The A-series volcanic ash is correlated to the upper bed of the black volcanic ash in the Kyushu region which was deposited in the Alluvium age.

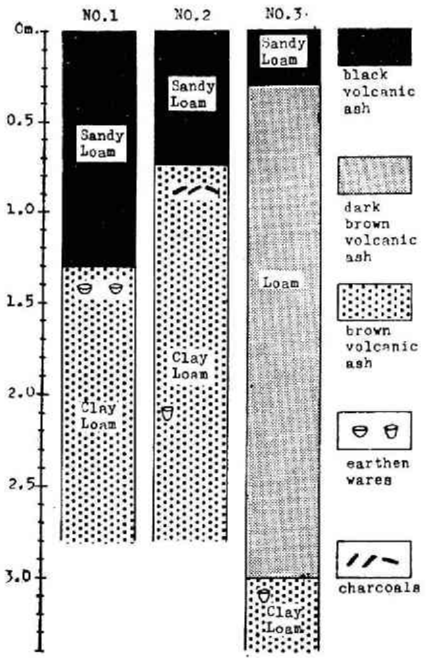

Fig. 19 Showing Positio n of the Archaeological Materials in the Soil Proffles.

3 The Narugo volcanic area

(1) The first stage

This stage is the period of deposition of the B-series volcanic ash in the Narugo volcanic area. The B-series volcanic ash was deposited by the volcanic activities after the mudflow areas were formed. The volcanic ashes after being erupted were changed into the yellowish brown volcanic ash by weathering and oxidation of the iron in particles of the ash. Namely, the color of the volcanic ashes was changed into a yellowish brown soil color. At present, the color of the B-series volcanic ash in this area is indicated mainly in Yellow brown 10YR5/6 of the standard soil color chart. The B-series volcanic ash which was spread widely in this area is underlain by mudflow materials and covered by the A-series volcanic ash (black color). The B-series volcanic ash is 5–40 centimeters in thickness in the area within a radius of about 2 kilometers from Katanuma, and deposited on the mudflow materials. The particles of this ash are progressed in leaching to an advanced degree, and no mineral fragments were recognized. However, as the result of heavy mineral analysis, augite, hypersthene, hornblende and magnetite etc., were found.

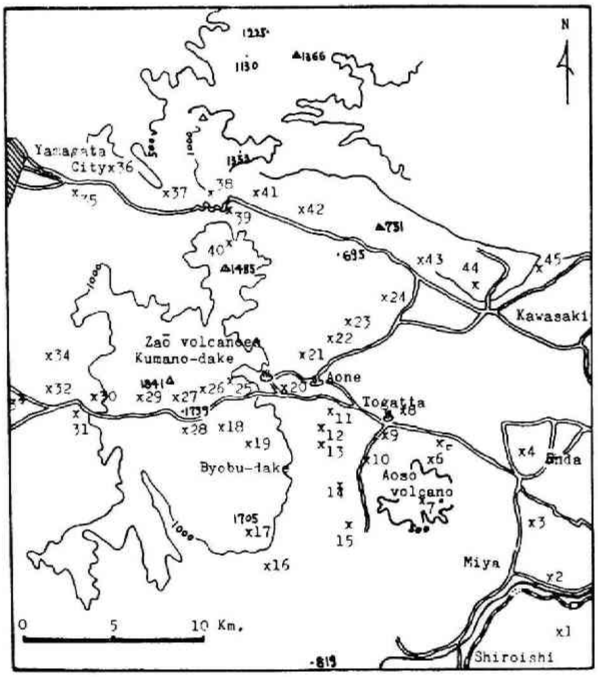

Fig. 20 Localities of the Columnar Sections in the Zaô Volcanic Area.

Some remains of Jōmon culture pottery of prehistoric age were found from the upper layer of the B-series volcanic ash which is covered by the A-series volcanic ash at Akabae, about 2 kilometers in northeast from Katanuma.

According to the report by Ishida (1965), such a volcanic ash distributed on the Ōsaki plain in the southeastern part of Narugo Town.

(2) The second stage

This stage is the period of deposition of the A-series volcanic ash in the Narugo volcanic area. The origin of this ash is supposed to be the explosion crater "Kata-numa". This ash accumulated to 2–10 centimeters in thickness in the area within a radius of about 2 kilometers from Katanuma, and deposited on the B-series volcanic ash.

A few mineral fragments such as plagioclase, pyroxene and quartz are recognized in the A-series volcanic ash.

The Narugo Basin was formed by the repetition of crustal movements in late Tertiary and early Quaternary (Kobayashi, 1951). And the lacustrine sediments

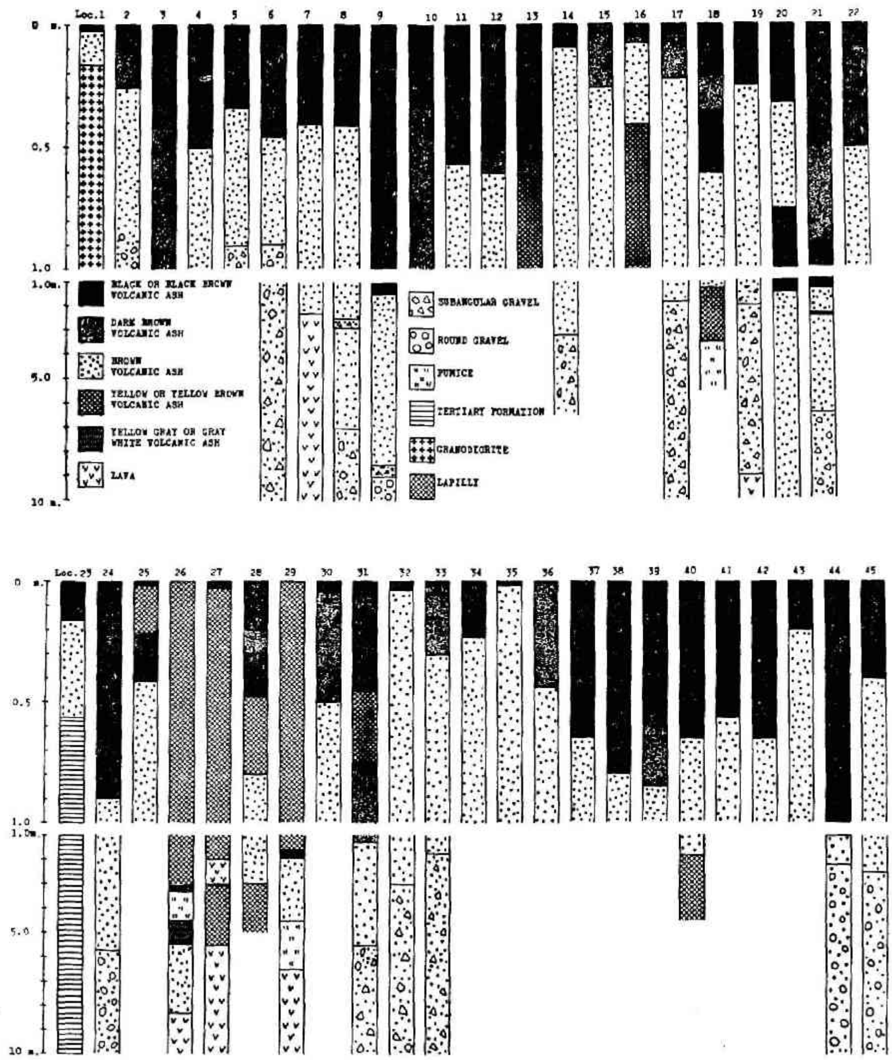

Fig. 21 Columnar Section s in the Zaô Volcanic Area.

were deposited in the Narugo Palaeolake which was formed by the crustal movements (Kato and Shimada, 1953). Several levels of erosional surface and fluvial terrace plains were formed (Omoto, 1966). These terrace surfaces are divided into I, IIa, IIb, III, IV and V surfaces (Murayama, 1969 c).

I surface This surface is the present river bed and flood plain along the Arao River.

IIa surface This surface is the latest terrace plain. The relative height of this terrace plain is 5–20 meters from present river bed. The materials of the terrace deposits consist of round gravels, subangular gravels, sand and clay. The gravels of these deposits are originated from the lava and block of the Narugo volcanoes.

IIb surface This surface as the fourth terrace plain spreads along the Arao River, at the surface of 100–200 meters above sea level. The relative height of the surface is 20–40 meters from the present river bed. The subangular gravels of this terrace deposits are supposed to have been originated from the lava of the Narugo volcanoes.

III surface This surface as the third terrace plain spreads along the Arao River, at the surface of 140–240 meters above sea level. The relative height of this surface is 40–60 meters from the present river bed.

IV surface This surface as the second terrace plain spreads in the western side and southeastern side of the Narugo volcanoes, at the surface of 150–200 meters above sea level. The relative height of this plain is 60–90 meters from the present river bed. The terrace deposits are consisted of subangular gravels.

V surface This surface as the first terrace plain spreads widely in the surrounding area of the Narugo volcanoes and in the area of the left bank of the Arao River, at the surface of 200–350 meters above sea level.

The A-series volcanic ash covered the hills, IIa, IIb, III, IV and V surfaces. Some remains of Jōmon culture pottery of prehistoric age were found from the

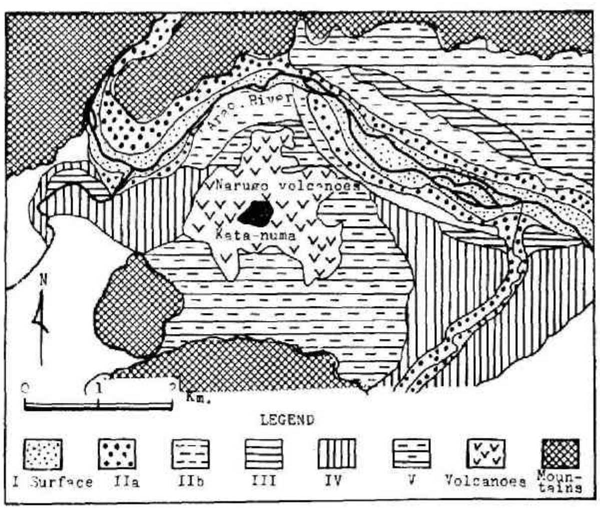

Fig. 22 Geomorphological Map of the Narugo Volcanic Area.

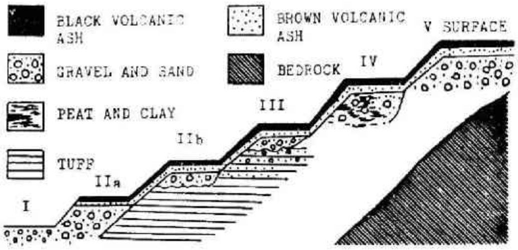

Fig. 23 Relationships between the Volcanic Ashes and Topographical Surfaces in the Narugo Volcanic Area.

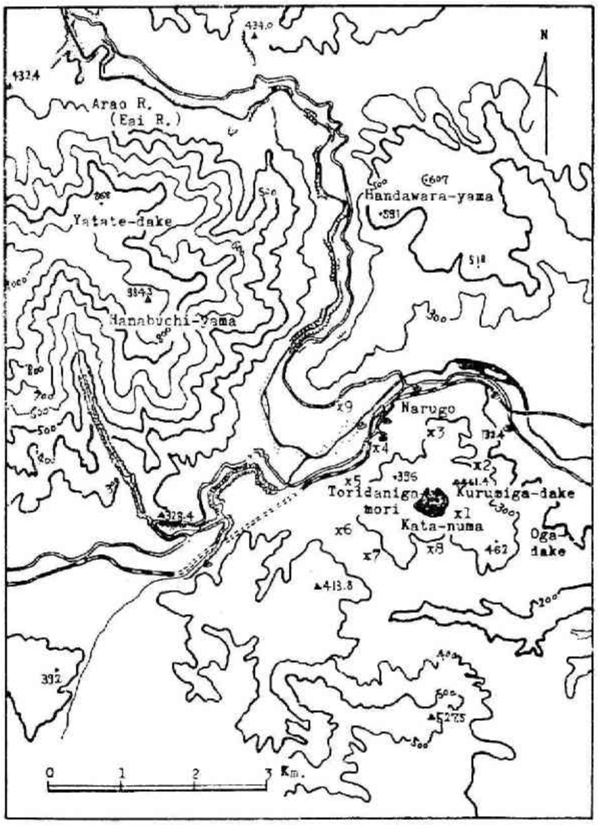

Fig. 24 Localities of Columnar Sections in the Narugo Volcanic Area.

III terrace plain under the A-series volcanic ash layer at Akabae. Hence, the upper layer of the B-series volcanic ash is supposed to have been deposited on the area before the Jōmon culture age. Then, the period of deposition of this upper layer

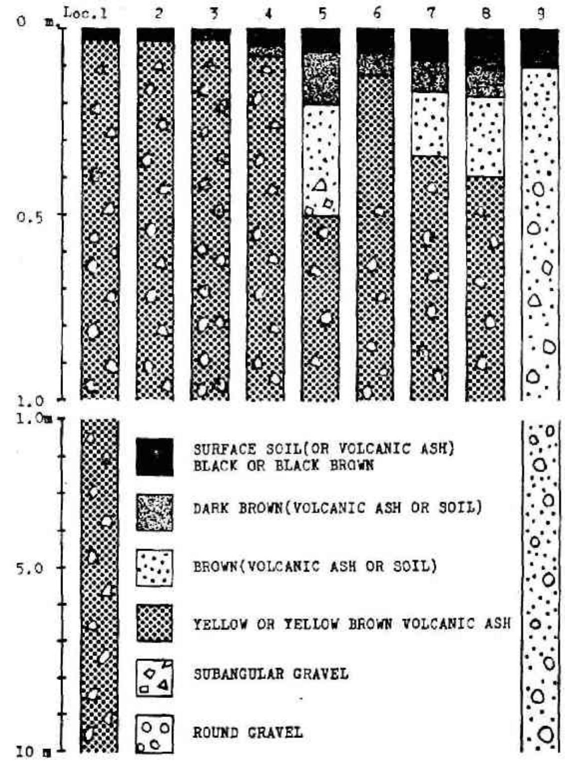

Fig. 25 Columnar Sections in the Narugo Volcanic Area.

of the B-series volcanic ash was earlier than the period of deposition of the brown volcanic ash in the other volcanic areas investigated.

The period of deposition of the A-series volcanic ash was since the Jōmon culture age, but this ash accumulated only to 2–10 centimeters in thikcness in the Narugo volcanic area. And, the particles of this A-series volcanic ash are advanced in degree of weathering. This ash is supposed to have been accumulated during early historic time.

4 The Onikôbe volcanic area

The topographical surfaces in the Onikōbe volcanic area are divided into the I, II, III and IV surfaces.

I surface This surface is the present river bed and flood plain of the upper stream of the Arao River and Ikusa-zawa.

II surface This surface is the latest terrace plain. The relative height of the surface is 10–40 meters from the present river bed. The materials of the terrace deposits consist of round gravels, subangular gravels of granodiorite and green tuff with clay.

III surface This surface is the higher terrace plain. The relative height of the surface is about 50 meters from the present river bed. The materials of the terrace deposits consist of round and subangular gravels of granodiorite, andesite and green tuff etc. These gravels are of 3 centimeters to 1 meter in diameter, with sand and clay. The surface is covered by the brown volcanic ash (B-series volcanic ash) layer of 0.5–5 meters in thickness.

IV surface The relative height of the surface is about 100 meters from the present river bed.

The brown volcanic ash (B-series volcanic ash) accumulates on the outer and inner mountains, and also on the II, III, IV surfaces. The soil color of this ash is indicated mainly in yellow brown 10YR5/6 of the standard soil color chart. This soil color resembles to the B-series volcanic ash of the Narugo volcanoes, and is not similar to the soil color of the B-series volcanic ash of the other volcanic areas investigated.

However, this ash layer is accumulated thickly, and includes plant leaves in the Katayama and Arayu geothermal areas. In view of this fact, this ash may have deposited in the paleo-lake of the areas.

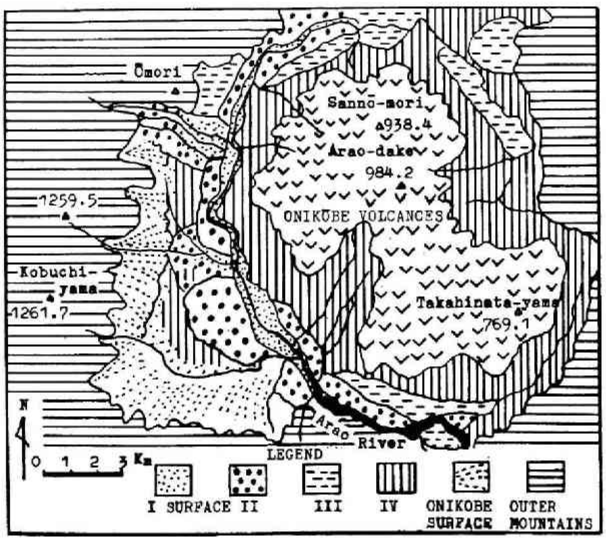

Fig. 26 Geomorphological Map of the Onikôbe Volcanic Area.

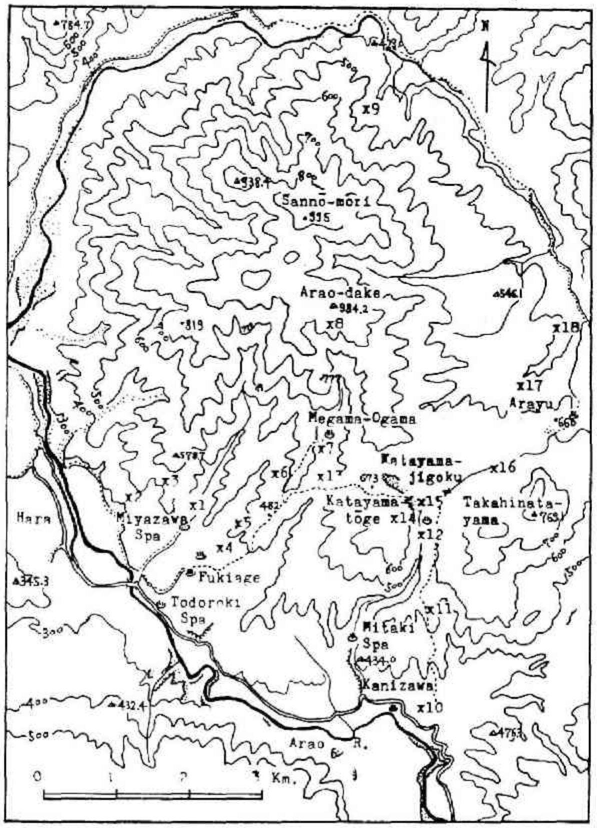

Fig. 27 Localities of Columnar Sections in the Onikôbe Volcanic Area.

After the deposition of the B-series volcanic ash, the A-series volcanic ash (black soil color) accumulated on the B-series volcanic ash layer. The thickness of this ash layer is 10 centimeters to several meters in the basin.

5 The Kurikoma volcanic area

After the mudflow areas were formed on the lower part of the crest, a volcanic ash was blown off by the volcanic activities from the pre-existing craters or existing craters, and widely spread on the Kurikoma volcanoes and also on the surrounding area, for instance, on the higher river terrace of the Iwai River in Ichinoseki City. This brown volcanic ash layer is about 1–3 meters in thickness on the higher terrace plain in Ichinoseki City. And, there is a layer of about 1–2 meters in thickness of the brown volcanic ash on the fanglomerate which is composed of round gravels with a matrix of brown volcanic ash in the higher river terrace, exposed at the

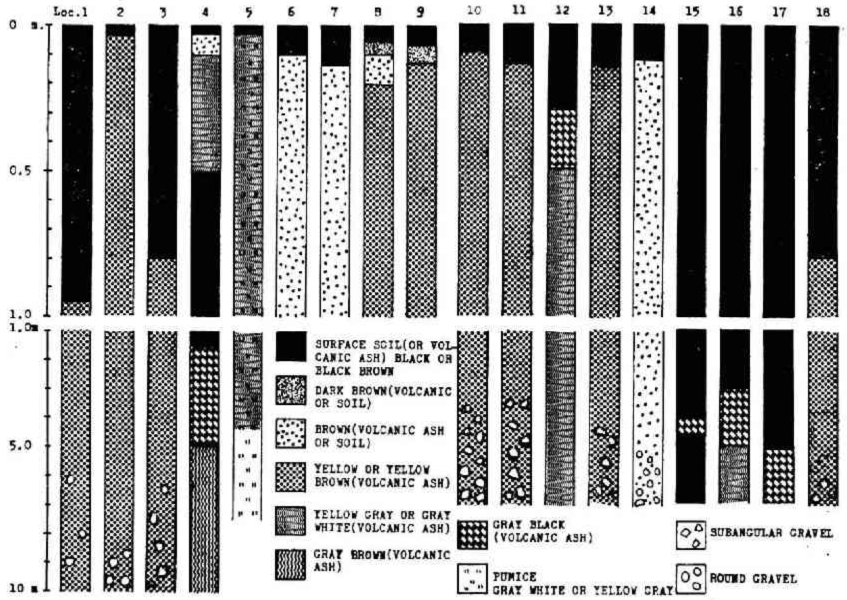

Fig. 28 Columnar Sections in the Onikôbe Volcanic Area.

ground of Ichinoseki Technical College, in Ichinoseki City.

When a volcanic ash was erupted by volcanic activity, the color of fresh volcanic ash shows black or gray color system in general. The fresh volcanic ash after being erupted was changed into a brown colored ash by weathering and oxidation of iron in the particles of the ash.

The brown volcanic ash of the Kurikoma volcanoes is indicated to be mainly Brown 10YR4/6 by the standard soil color chart. This brown volcanic ash is correlated to the B-series volcanic ash in the other volcanic areas investigated. The brown volcanic ash of the Kurikoma volcanoes is deposited widely on the areas of Kurihara, Tamatsukuri, Nishi-iwai and Okatsu Counties, and formed rich soil for plant's growth.

Many remains of Jōmon culture pottery of prehistoric age were found from the upper layer of this brown volcanic ash at Hanayama, Himematsu, Sannō of Ichihasama Town etc.

During historic time, there are no records to prove the accumulation of volcanic ejecta by the volcanic activities.

Podzolization in the brown volcanic ash layer is found at the northern slope of the summit of Kurikoma-yama. This phenomenon is presumed that the podzolization was much more favored by long winters and short summers under humid climate.

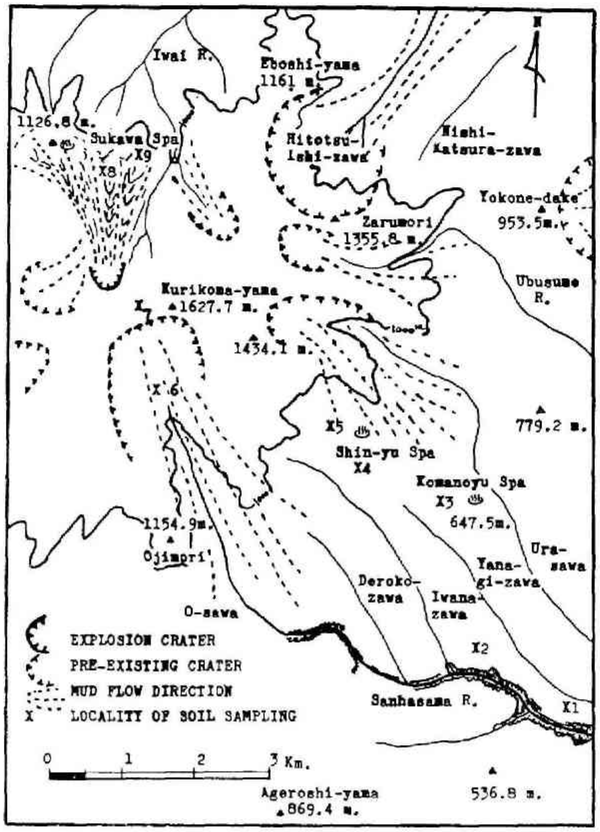

Fig. 29 Geomorphological Map of the Kurikoma Volcanic Area.

6 The Iwate volcanic area

According to the paper by Ishizuka (1948), the volcanic ashes which deposited in the Iwate volcanic area are divided into three series volcanic ashes, such as the Iwate A, B and C-series volcanic ashes. The Iwate A and B-series volcanic ashes show the black soil color, and the Iwate C-series volcanic ash belongs to the brown volcanic ash.

According to the other paper by Nakagawa etc. (1963), the brown volcanic ashes are classified into the Shibutami volcanic ash and Wakare volcanic ash.

However, the writer attempts to classify that the stages of deposition of the volcanic ashes which erupted from the Iwate volcanoes on the surface of the earth are mainly divided into two stages judged from circumstances of deposition of the volcanic ashes and soil colors etc. These two stages are, (a) The first stage – This

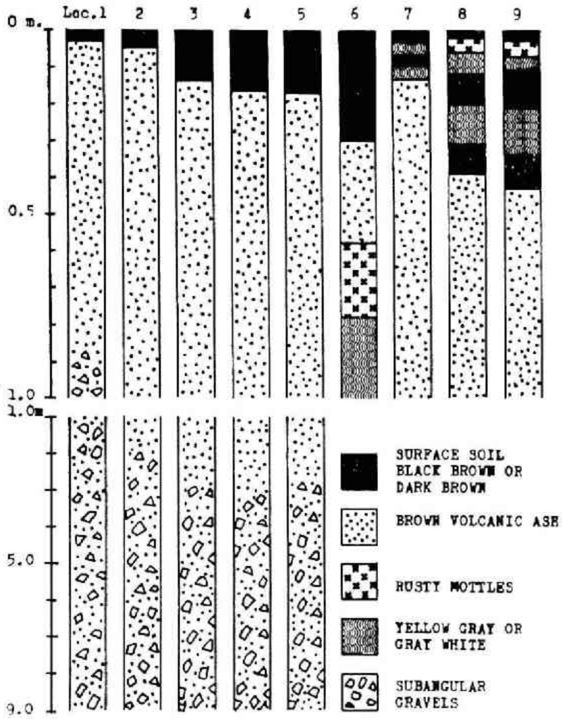

Fig. 30 Columnar Sections in the Kurikoma Volcanic Area.

stage is the period of the B-series volcanic ash. (b) The second stage – This stage is the period of deposition of the A-series volcanic ash.

The river terraces along the Kitakami River at the southern foot of the Iwate volcanoes were divided into five terrace plains by Tayama and Tsuchita (1933), such as the 200 meters', Shizukuishi, Sori, Iwamochi and Gomyojin terrace plains. However, Nakagawa and others (1963) tried to classify that the terrace plains are divided into three plains in the same areas, and named the alluvial plain, Morioka and Shibutami terrace plains.

The activities of Kakkonda volcano was closed with the eruption of the Koiwai mudflow and Aoyama-chō mudflow. The Shizukuishi terrace plain as a higher terrace is formed along the Shizukuishi-gawa course after the eruption of the Koiwai mudflow and Aoyama-chō mudflow. The Iwamochi terrace plain as a lower terrace is deposited after the formation of the Shizukuishi terrace plain. The higher and lower terrace plains underlain by the Takizawa and Hiradate mudflow materials at the southeastern foot of the volcanoes.

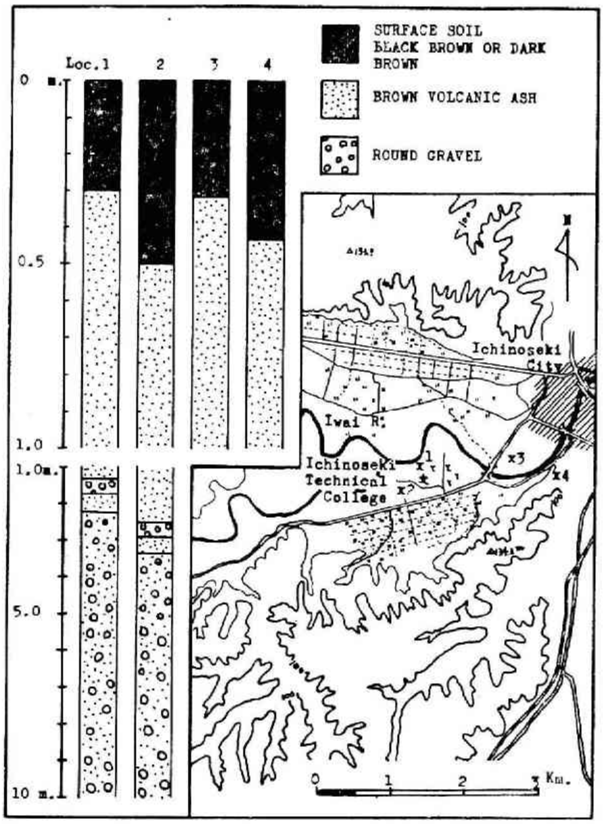

Fig. 31 Columnar Sections and their Lolcalities in the Eastern Part of the Kurikoma Volcanoes, near Ichinoseki City.

As already mentioned, the distribution of the B-series volcanic ash is wide spread and accumulated to about 20 centimeters or more than 10 meters in thickness. The B-series volcanic ash covers the mudflow materials and higher river terrace plain. For instance, the Shibutami volcanic ash is accumulated to a thickness of about 2 meters near the Koiwai Station, and underlain by the higher terrace plain.

The Wakare volcanic ash covers the Shibutami volcanic ash as an unconformity, and is correlated to the Tachikawa loam of the Kantō District. It has a parting ash layer, and or covered by the A-series volcanic ash in a limited area where located in the high ground about several hundred meters above sea level.

The parting layer of the black volcanic ash in the B-series volcanic ash layer is shown to be composed of grains as large as sands. Then the black parting layer is supposed to be formed as the result of unprogressive leaching of the particles, and not so advanced oxidation of iron in the particles of volcanic ash because of the large grain size.

The upper layer of the B-series volcanic ash which was deposited on the black parting layer is correlated to the brown volcanic ash which yielded the remains of pottery with a pinnate pattern in the last stage of the Jōmon culture. This brown ash layer may have been deposited during the Atlantic and Sub-boreal period. It is thought that the parting layer of the black volcanic ash was deposited under a natural environment of cold climate, and this may explain the unprogressed leaching.

The lower layer of the B-series volcanic ash which was deposited under the parting layer is correlated to the Tachikawa loam layer. Therefore, the writer is inclined to the conclusion that the black parting layer was deposited in the Preboreal or Boreal period.

The stages of deposition of the A-series and B-series volcanic ashes are described in more detail as follows.

(1) The first stage

This stage is the period of deposition of the B-series volcanic ash (brown or yellowish brown color) on the Iwate volcanoes and their vicinity. The B-series volcanic ash is mainly due to the volcanic activities of the west Iwate and east Iwate volcanoes.

The soil color of the B-series volcanic ash is indicated mainly in Brown 7.5 YR4/6–Brown 10YR4/4, and the yellowish brown ash shows Yellow brown 10YR5/8 of the standard soil color chart. The B-series volcanic ash accumulated to about 20 centimeters to more than ten meters in thickness.

Some remains of the Jōmon culture pottery of prehistoric age were found from the upper part of the B-series volcanic ash layer in the vinicity of the Higashihachimantai station at the northern foot of the east Iwate volcanoes.

The Shibutami volcanic ash deposited on the areas of Tamayama and Takizawa at the southeastern foot of the volcanoes, and it is more than 8 meters in thickness. A typical locality showing the sequence of the Shibutami volcanic ash layer is at Shibutami, Tamayama Village. The soil color of this ash is red brown.

The Wakare volcanic ash is distributed on the Takizawa area from the northern side of the Shizukuishi-gawa, and accumulated about 2 meters in thickness. This ash shows dark brown color, and is in the state of clay.

The upper part of the B-series volcanic ash layer in the high grounds more than several hundred meters above sea level has a parting layer of the black volcanic ash.

(2) The second stage

This stage is the period of deposition of the A-series volcanic ash which covers the B-series volcanic ash. This A-series volcanic ash was deposited later than the B-series volcanic ash. The A-series volcanic ash is not so advanced in the state of clay even though both weathering and leaching show their effects. A boundary line of the layer is shown clearly between the A-series and B-series volcanic ash which underlies the A-series volcanic ash.

The A-series volcanic ash is accumulated to a thickness of 0–1 meter above the B-series volcanic ash layer. However, the A-series volcanic ash layer is accumulated thicker on the eastern foot of the east Iwate volcanoes than elsewhere. The A-series volcanic ash is considered to have been deposited during historic time. So far as is shown by the historic records compiled by the Meteorological Bureau (1959). The eruptions took place in 1686 (February 29-March 3), 1687 (March 7–16), 1689, 1719 (January), 1823, 1919, 1939 (July, August, September) etc. These records are of importance to know the age of the distribution of volcanic ejecta, and several of them require a short description here.

(a) In 1686, a large amount of volcanic ashes were blown off from February 29 to March 1.

On the 2nd of March, earthquakes occurred accompanied with rumbling noise, and mudflow rushed down to the Kitakami River. This mudflow carried down many houses and numerous trees to the river.

On the 3rd of March in the same year as above, black volcanic ash was blown off and continued to fall during 10 days, and this volcanic ash accumulated to more than 30 centimeters in thickness in the Ippongi area at the eastern foot of the volcanoes. Many houses which existed within 4 kilometers from the crater were damaged.

(b) In 1689, earthquakes occurred and continued from the 7th to 15th of March.

On the 26th of May, a strong earthquake happened.

On the 27th of May, the ground at Nagase just in front of Fudō was cracked, and steam or occasional emission of smoke erupted from it.

In June, rumbling noise occurred, and volcanic ashes were blown out.

(c) In 1689, a small activity happened, but the details are unknown.

(d) In January of 1719, a large explosion occurred, and lava flowed down to the northeastern foot of the volcanoes.

(e) In 1823, a small activity occurred, but the details are unknown.

(f) An explosion happened in 1919 at Dai-jigoku situated in the eastern part and about 3 kilometers distant from the summit. The details of the activity are unknown.

(g) Several small activities occurred in 1939.

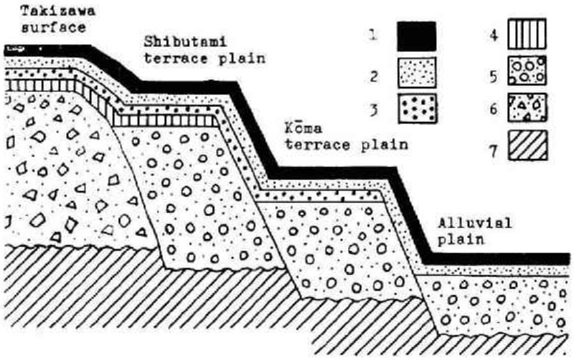

Fig. 32 Relationships between the Volcanic Ashes and Terrace Plain in the Iwate Volcanic Area.
1: Black volcanic ash, 2: Brwon volcanic ash (including a black volcanic ash parting layer), 3: Wakare volcanic ash, 4: Shibutami volcanic ash, 5: Gravel and sand, 6: Mudflow material, 7: Bedrock

7 The Yake-yama volcanic area

(1) The first stage

This stage is the period of deposition of the B-series volcanic ash (brown soil color) on the lava, volcanic blocks and mudflow materials in the Yake-yama volcanic area. The B-series volcanic ash was deposited by the volcanic activities of Kuroishi-mori, Tsuga-mori and Yake-yama. The volcanic ashes after being erupted were changed into the brown volcanic ash by weathering and oxidation of the iron in particles of the ash. Namely, the color of the volcanic ashes was changed into a brown color.

The B-series volcanic ash which was deposited widely on the area is subjacent to lapilli, sand and black volcanic ash in the surrounding area of Yake-yama.

The mineral components of the B-series volcanic ash are progressed in degree of weathering and the state of clay, but minute crystals of plagioclase can be recognized. However, the crystals of plagioclase of the B-series volcanic ash are few in ratio compared with those in the black volcanic ash and lava. Almost all of the mafics in the ash consist of augite, hypersthene and magnetite etc.

The upper part of the B-series volcanic ash layer has a parting layer of the black volcanic ash in a limited area where is located in the high ground about several hundred meters above sea level. The parting layer of the black volcanic ash in the B-series volcanic ash layer is shown to be composed of grains as large as sands. So the black parting layer is supposed to be formed as the result of unprogressive leaching of the particles, and not so advanced oxidation of iron in the particles of volcanic ash. It is thought that the parting layer of the black volcanic ash was deposited under a natural environment of cold climate, and this may explain the unprogressed leaching. The upper layer of the B-series volcanic ash which was deposited on the black parting layer is correlated to the brown volcanic ash which yielded the remains of pottery in the last stage of the Jōmon culture. This brown volcanic ash layer may have been deposited during the Atlantic and Sub-boreal period.

(2) The second stage

This stage is the period of deposition of the lapilli, volcanic sand and A-series volcanic ash which covers the B-series volcanic ash. These volcanic fragmental materials were deposited later than the B-series volcanic ash. The A-series volcanic ash is not so advanced in the state of clay even though both weathering and leaching show their effects. A boundary line of the layers is shown clearly between the A-series and B-series volcanic ashes which underlies the A-series volcanic ash layer.

The A-series volcanic ash is accumulated to a thickness of 0–20 centimeters above the B-series volcanic ash layer. Lapilli and volcanic sand are distributed in the area within the limits of about 1 kilometer east of the crater, and the A-series volcanic ash is distributed in a rather wide area within the limits of about 3 kilometers east of the crater. Lapilli and volcanic sand are the most outstanding ejecta of this area, being well exposed in the cliffs and summits. They consist of plagioclase, augite, hypersthene and magnetite as well as of tuffaceous substances and minute fragments of two pyroxene andesite. These volcanic fragmental materials which were deposited on the surface of the earth are supposed to have accumulated mainly during historic time.

8 The Hachiman-tai volcanic area

After the mudflow areas were formed on the lower parts of the crests, a volcanic ash was blown off by the volcanic activities from the explosion craters and pre-existing craters, and widely spread on the Hachiman-tai volcanic area. This volcanic ash is now showing brown soil color and indicate mainly Yellow brown 10YR5/6 by the standard soil color chart. This brown volcanic ash is correlated to the B-series volcanic ash in the other volcanic areas investigated.

The brown volcanic ash layer is about 0–10 meters in thickness on the mudflow materials. Also this volcanic ash deposits on the higher terrace plain. And the upper part of the brown volcanic ash layer accumulates on the lower terrace plain.

The black or blackish brown volcanic ash is deposited on the brown volcanic ash layer in the surrounding areas of Hachiman-tai. The layer of the black or blackish brown volcanic ash is about 10–20 centimeters in thickness in the area of the Higashi-hachiman-tai Station at the southeastern foot of the volcanoes. However, this black volcanic ash is supposed to have been erupted out from the Iwate and Yake-yama volcanoes etc., and accumulated in this area. This fact is inferred by the distribution and accumulation of the volcanic ejecta.

Many remains of Jōmon culture pottery of prehistoric age were found from the upper part of the brown volcanic ash or lower part of the blackish brown Volcanic ash about 20 centimeters below the surface near the Higashi-hachiman-tai Station at the eastern foot of Hachiman-tai. In judgement of such a fact, the black volcanic ash was deposited by the volcanic activities after the era of Jōmon culture. And the volcanic ash which was deposited near the boundary line of the black and brown volcanic ashes is supposed to have been accumulated during the stage of the Jōmon culture era.

In the Northern Kantō Plain, the stone artifacts excavated from the volcanic ash layer (Kantō Loam) are classified typologically into the several industries, such as pebble-tools or hand-axes, crudes, backed blades, points, microblades and microcores. These are correlated with the geological sequence. Namely, the pebble-tools are found from the lower loam (Shimo-sueyoshi Loam Layer). The hand-axes are found from the middle loam (Musashino Loam Layer). And the backed blades, points, microblades and microcores are found from the upper loam (Tachikawa Loam Layer) in the Kantō Loam Layers (Serizawa, 1963) (Kantō Loam Research Group, 1965).

In Kyushu Region, in the younger stage, the central cones of the volcanoes began to act a violent explosive eruption which ejecta was thrown out. The volcanic ash, scoria and pumice wafted by winds, and covered the extensive areas. These ejecta formed the younger loam in this region. Some of these activities continued to the Recent, and supplied the essential part of the black volcanic ash layer. This black volcanic ash layer contains ceramics of the Jōmon culture era, Yayoi and later culture eras. So, the chronological division of ash layers is classified (Gohara, 1963).

In the Hachiman-tai volcanic area, the black or blackish brown volcanic ash is supposed to have been deposited a little earlier than the black volcanic ash of the Zaō volcanoes. However, the black volcanic ash in the area of the Higashi-hachiman-tai Station may be correlated to the black volcanic ash of Kyushu Region.

As already mentioned, in the Zaō volcanic area, the fresh volcanic ash of the black color is thought to have changed into the brown colored volcanic ash after more than a period into the brown colored volcanic ash after more than a period of 1,000 years, judging from the remains of straw-rope pattern pottery of the Jōmon age. But in the Hachiman-tai volcanic area, the black volcanic ash will be need longer time to be changed into a brown colored volcanic ash, than the period of 1,000 years, judging from the position of the remains.

A prehistoric site in a volcanic ash layer has been able to estimate the age of the pyroclastic by determination of the age in the prehistoric site of the archaeological materials. And obsidian stone implements made by aborigines in a volcanic ash layer are able to estimate the age of the volcanic ash layer by the thickness of the hydrated surface layer which has been formed outside of the obsidian.

9 The Hakkôda volcanic area

After the mudflow areas were formed on the lower parts in the volcanic area, volcanic ashes were blown off from the explosion craters at the last stage of the volcanic activity. These volcanic ashes are widely spread and accumulated on the Towada volcanic ash layer, and showing mainly yellowish brown or brown soil colors. One of them consists of coarse sand called "Awa-zuna" means "sand like a millet seed." Awa-zuna is composed of two pyroxene andesite fragments. It is infferred under the microscope.

The topographical surfaces in the Quaternary formation are classified into several surfaces. And the surfaces are called by different names depending upon the areas, also the relationship between the surfaces and volcanic ashes are investigated (Sakai et al., 1967) (Mizuno, 1961) (Iwai, 1951) (Nitobe, 1964) (Onuki et al., 1963).

Then, the topographical surfaces here are divided into the higher surface (135–100 meters above sea level), Nanahyaku (100–60 m.), Tengutai (80–40 m.). Takadate (50–20 m.), Hachinohe (35–20 m.) surfaces and alluvial plains. These surfaces and alluvial plains are covered by the Towada and Hakkōda volcanic ashes.

The Tengutai volcanic ash covers directly on the Tengutai surface, and is consisted of sand and sandy silt, showing reddish brown color. This ash is supposed to have been deposited from the Towada volcanoes.

The Hachinohe volcanic ash covers conformably the Hachinohe surface, and is showing reddish brown color. This volcanic ash layer includes a pumice layer. The origin of this volcanic ash is supposed to have been deposited from the Towada volcanoes.

The Sanbongi volcanic ash layers are divided into two layers, such as the lower and upper layers. The lower layer of the Sanbongi volcanic ash deposits directly on the Hachinohe surface, and showing a yellowish brown color. This lower layer also includes a whitish gray pumice layer.

The upper layer of the Sanbongi volcanic ash underlain by the alluvial plain is consisted of "Awa-zuna", and shows a yellowish brown color. The Sanbongi volcanic ash is supposed to have been acumulated from the Hakkōda volcanoes. Such as, the volcanic ashes from the Hakkōda volcanoes are widely deposited on the surface of the area in Aomori Prefecture.

In the area, the color of the volcanic ash is a conspicuous feature of the landscape. Among the commonest colors are brown, yellowish brown and blackish brown. These are due to different forms, degree of hydration, and intensities of the oxides of iron which exist as thin coatings or staings upon the particles of volcanic ash. Black or dark brown colors in surface layers usually, but not always, denote a considerable content of organic mater. Black or dark brown volcanic ash in the surface layer, in the Hakkōda volcanic area, contents largely humus.

The soil color of the ash changes, not only from place to place but also from the surface downward from one time to another. Wet ashes generally are darker in color than the same ashes when dry. These volcanic ashes have formed by certain developmental processes. Loam develops from volcanic ash material regardless of environmental conditions.

A parting layer of black brown volcanic ash exists in the yellowish brown volcanic ash layer on the southeastern flank of Takada-ōtake near the Yachi Spa. A thickness of the parting layer is 5 to 20 centimeters. The upper layer of the yellowish brown volcanic ash which was deposited on the black parting layer is correlated to the yellowish brown volcanic ash which yielded the remains and stone circle at O-yu in Akita Prefecture. It is thought that the black parting layer in the yellowish brown volcanic ash layer was deposited under a natural environment of cold climate.

There are also podzols on the southeastern flank of O-take. Podzols are the typical mature soils of regions having subarctic climate. Although it is known to occur in the humid tropics and subtropics, podzolization is much more favored by long winters and short summers. The mature podzol is developed under a natural vegetation of forest, but in this case it is mainly coniferous forest. The area of podzols on the southeastern flank of O-take is covered by coniferous forest such as *Abies Mariesii* Masters and *Pinus pumila* Regel. The profiles of the podzols are shown in the figure. The effect of long cold winter and moderate summer temperature and a forest litter of resinous pine needles is to retard bacterial action and to

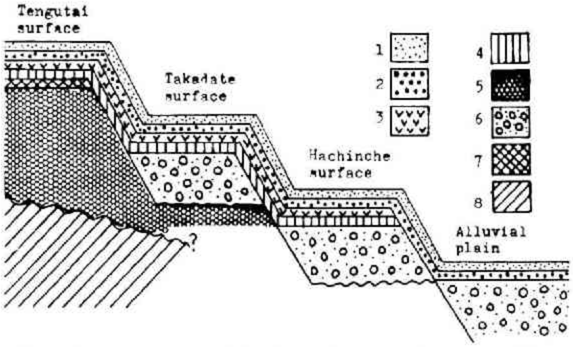

Fig. 33 Relationships between the Volcanic Ashes and Terrace Plain in the Hakkôda Volcanic Area
1: Hakkôda volcanic ash, 2: Sanbongi volcanic ash (upper layer), 3: Sanbongi volcanic ash (lower layer), 4: Hachinohe volcanic ash, 5: Noheji formation, 6: Gravel and sand, 7: Tengutai volcanic ash, 8: Bedrock (Tertiary formation)

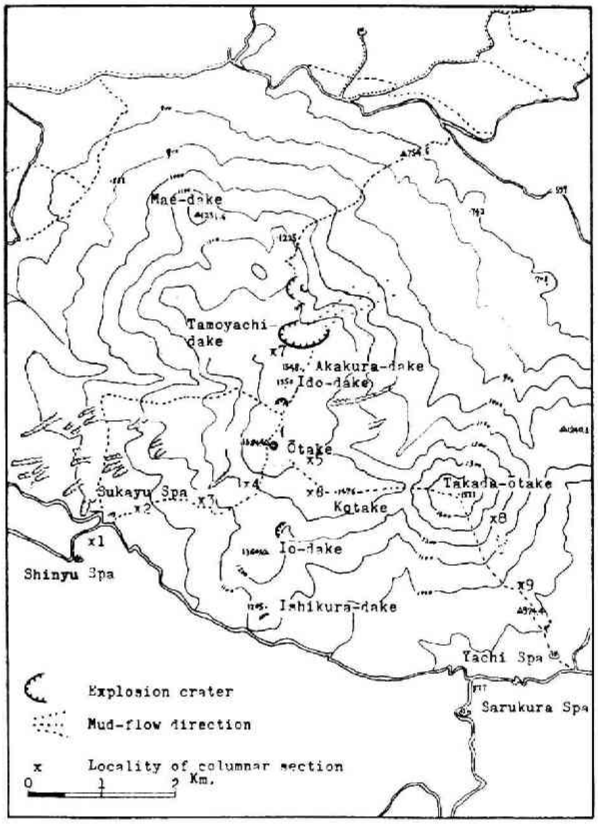

Fig. 34 Geomorphological Map of the Hakkôda Volcanic Area.

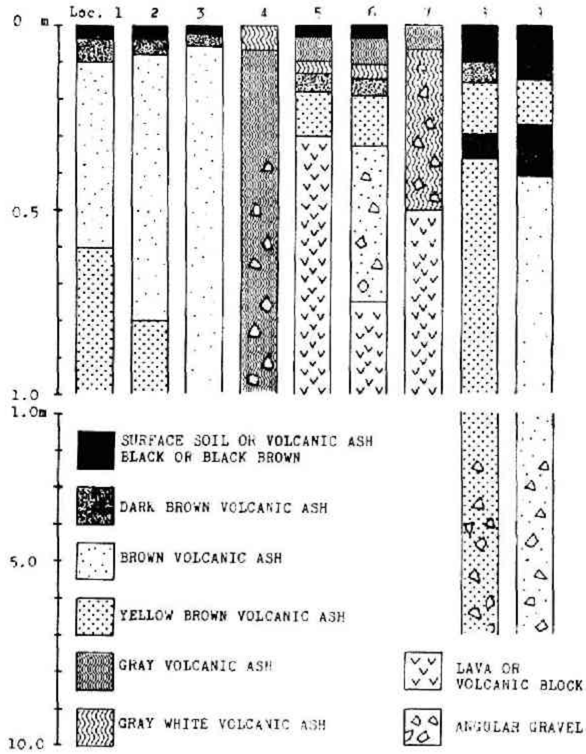

Fig. 35 Columnar Sections in the Hakkôda Volcanic Area.

permit the formation of a brown layer of raw humus or half-decomposed organic remains, which represents the accumulation of many years.

The decaying vegetation with the upper soil layer the A_0-horizon is not accomplished, and the A_1-horizon with humus shows a blackish brown color, and the line of separation between raw surface humus and the mineral soil is sharp. A thickness of the A_0 and A_1-horizons are 2 to 3 centimeters. Underneath the layer of raw humus the A_2-horizon of a mature podzol is leached of its iron and readily soluble mineral, and, by eluviation, it has lost most of its clay and colloidal constituents also. Through loss of iron it is bleached to a grayish white color. This A_2-horizon has 10 to 15 centimeters in thickness. Beneath a bleached A_2-horizon is a brown color, acid B_1-horizon which is strongly illuviated. In it is deposited some quantities of the iron and other minerals leached from above and even part of the finely divided or colloidal clays and organic material which have passed through the A-horizon. The C-horizon is composed of the brown volcanic ash or weathered lava.

IV Some characteristics of the volcanic ashes

1 The Bandai volcanic area

The physical and chemical properties of the ashes are shown in order to know the characteristics of the volcanic ashes, also the distinction between the A and B-series volcanic ashes in the Bandai volcanic area.

The volcanic ahes of the Bandai volcanic area include 1–15 percent humus. Of this value, the A-series volcanic ash includes 3.5–14.3 percent humus, and the B-series volcanic ash includes 1.0–7.8 percent humus. Therefore, the A-series volcanic ash is rich in humus compared with the B-series volcanic ash in the same soil profile. One of the reasons for the black soil color of the A-series volcanic ash is probably due to the humus. The soil acidity of the ashes is pH 5.3–5.7 in H_2O, or pH 4.8–5.4 in KCl. There is no remarkable distinction in soil acidity between the A-series and B-series volcanic ashes. However, these values of soil acidity are more strongly acidic than those of th Zaō, or the Iwate volcanic ashes, but show same acidic value in comparison with the Kurikoma volcanic ash. Generally speaking, calcium in the soil is derived from plagioclase, and magnesium is from olivine, as a result of weathering. In the volcanic ashes of the Bandai area, calcium exceeds magnesium quantity in the ratio of the chemical composition. And the A-series volcanic ash is rich in calcium compared with the B-series volcanic ash.

Some black or dark brown volcanic ash is recognized as a parting layer in the B-series volcanic ash layer. These parting layers are approximately 10–13 centimeters in thickness, and 50–80 centimeters deep from the surface of the earth. The particles of the parting layer are not so advanced in leaching compared with the B-series volcanic ash. These parting layers are thought to have been deposited under cold climatic conditions.

2 The Zaō volcanic area

The mineral components of the A-series volcanic ash are not so advanced in degree of leaching, and are rich in plagioclase fragments. A large-sized plagioclase fragment measures about 0.4 millimeters in diameter.

The mineral components of the B-series volcanic ash are progressed in degree of leaching and the state of clay, but small fragments of plagioclase can still be recognized. However, the plagioclase fragments of the B-series volcanic ash are few in ratio compared with those in the A-series volcanic ash. Almost all of the mafics in the ashes consist of augite, hypersthene and magnetite etc.

The mineral composition in the ashes is shown in Table 3.

The Kantō loam (The Knatō Laom Res. Group, 1956), and brown volcanic

Table 1 Some characteristics of the volcanic ashes in the Bandai volcanic area (Murayama, 1968a)

Localities	Depth from the surface (cm.)	Soil color	pH (by glass electrode)		Mechanical analysis by ASK elutriation %				Humus %	Exchangeable bases mg/100 m.	
			H_2O	KCl	Coase sand	Fine sand	Silt	Clay		CaO	MgO
1	0- 3	Black 7.5YR2/1	5.6	5.2	29.7	29.7	34.4	6.2	6.6	174	16
	3-20	Brown 7.5YR/4/3	5.6	5.3	25.2	25.4	36.7	12.7	7.8	244	31
	20-50	Light orange brown 7.5YR6/6	5.5	5.2	27.8	27.8	22.3	0.3	2.8	131	21
4	0-12	Dark brown 7.5YR3/3	5.7	5.2	24.2	30.0	24.4	21.4	7.8	259	36
	12-30	Brown 7.5YR4/6	5.8	5.4	39.3	22.8	28.6	9.3	4.6	229	53
9	0-48	Black 7.5YR2/2	5.7	5.3	24.8	24.8	44.4	6.0	14.0	178	21
	48-	Light brown 7.5YR5/6	5.3	4.8	8.2	18.4	35.8	37.6	1.5	165	8
15	0-20	Black 7.5YR2/2	5.5	5.2					3.5		
	20-42	Dark brown 7.5YR3/4	5.4	4.8					3.0		
	42-	Light orange brown 7.5YR7/6							1.0		
22	0-52	Black 7.5YR2/1	5.4	5.1	27.1	31.8	21.9	19.2	7.3	108	21
	52-	Yellow brown 2.5YR5/6	5.3	4.8	27.1	36.3	20.5	16.1	3.3	100	15
25	0-55	Black 7.5YR2/2	5.6	5.3	22.2	29.4	36.6	11.8	14.3	327	11
	55-	Light brown 7.5YR5/6	5.4	4.9	8.5	18.1	35.4	38.0	1.2	155	7

Table 2 Minerals in the volcanic ashes.

Locality	Ashes	Depth from the surface cm.	Mafics %	Plagioclase %	Pumice, rock fragments %
Nanokahara Loc. 9	A-series	10	55	40	5
Misumi Loc. 14	B-series	10	25	10	65

Table 3 Heavy mineral contents of the volcanic ashes (by Toulet solution)

Locality and depth from the surface	Soil color	Totals of heavy minerals mg.	Hypersthene %	Augite %	Magnetite %
Shimuzuhara					
12 cm.	Black brown 10YR 2/3	679.7	48.2	38.4	13.4
52 cm.	Brown 10YR 4/6	1085.8	48.0	37.3	14.7
110 cm.	Black brown 10YR 2/3	1281.6	52.3	27.7	20.0
188 cm.	Brown 10YR 4/6	1497.3	45.9	37.2	16.9
Nanokahara					
20 cm.	Black brown 10YR 2/3	923.3	53.4	30.3	16.3
100 cm.	Brown 10YR 4/6	1484.2	45.7	37.5	16.8

ash of the Kurikoma volcanoes (Murayama, 1966b) which were investigated by the writer also include small plagioclase fragments, but the volcanic ashes of the Zaō volcanoes, especially the A-series volcanic ash is rich in plagioclase fragments. This fact is a distinguishing characteristic of the volcanic ashes in the Zaō volcanic area.

As the result of heavy mineral analysis, augite, hypersthene and magnetite were found, but hornblende was not recognized in the ashes. However, there is no remarkable distinction between the black volcanic ash and brown volcanic ash so far as the composition of the heavy minerals is concerned. From the result of mineral analysis and components, these ashes are presumed to have been derived from similar parent rocks.

According to the paper by Kobayashi (1963), in Ina valley of Nagano Prefecture, the Older Laom underlies the Osakada Loam with slight hiatus and the lower horizon of the Older Laom is much clayey and rich in magnetite; it also includes hornblende. The Older Loam at the eastern foot of Yatsuga-dake is characterized by the excessive amount of magnetite and the presence of hornblende including oxyhornblende. According to the report by Gōhara (1963), in the Ōsumi peninsula of Kyushu, the volcanic ash which erupted from Sakurajima includes hornblende.

The Kantō plain is thickly covered by the Quaternary volcanic ashes that were supplied from the volcanic chain running from the north to the west of the region, and offers one of the type areas for the tephrochronological study in Japan as well as the type areas of the Japanese marine Pleistocene. Most of the Quaternary volcanic ashes distributed in the Kantō region are composed of weathered ashes of the Pleistocene epoch, and have been called "the Kantō Loam." The Kantō Loam formation is generally thick on the higher teraces and thin on the lower ones. In South Kantō, the Loam which conformably covers the Tachikawa terrace gravels is named the Tachikawa Loam, and it merges downward into the sediments of the Musashino terrace called the Musashino Loam. The Shimosueyoshi Loam conformably lies on the marine Shimosueyoshi formation (Upper Pleistocene). The lowest division of the Kantō Loam is the Tama Loam which is defined as the loam which covers the Byobugaura formation (Middle Pleistocene) or its correlative on the Tama terraces. Based upon the result of heavy mineral analysis of the Kantō Loam (The Kantō Loam Res. Group, 1965) (Toya, 1962), Tama Loam and Shimosueyoshi Loam, all are very rich in hornblende, and poor in olivine. Hornblende has not been recognized in the Musashino Loam and Tachikawa Loam, and the latter is characterized by the very rich content of olivine compared with the other loams.

In the volcanic ashes deposited in and around Sendai (The Kantō Loam Res, Group, 1965), the Medeshima volcanic ash and Koeji volcanic ash have hornblende. According to the report by Ishida (1965), the volcanic ash distributed on the Ōsaki plain in the northern part of Sendai carries hornblende in 50–70 parcent in the composition of the heavy minerals. However, the Nagano and Hirasawa volcanic ashes on the Zaō volcanoes and its surrounding area are poor in hornblende, and rich in magnetite and hypersthene (The Kantō Loam Res. Group, 1965). The black volcanic ash which erupted from Okama, and the brown volcanic ash which is presumed to be a correlative of the upper part of Nagano volcanic ash are characterized by having no olivine, or hornblende. Hence, there can not be recognized a distinction between the black volcanic ash and brown volcanic ash so far as concerns the composition of the heavy minerals. Since the mineral composition of the Medeshima volcanic ash and Koeji volcanic ash are similar to the volcanic ashes distributed in the northern part of Sendai, they are considered to have erupted from some other sources with the exception of the Zaō volcanoes.

The physical and chemical properties of the ashes were determined in order to know the characteristics of the volcanic ashes in the Zaō volcanoes and their vicinities, also to know the distinction between the black and brown volcanic ashes, and the difference between the upper part and lower parts of the ash layer, the relation between the properties of the ashes and distance from Okama, etc.

Some physical properties of the volcanic ashes at Nanokahara, the eastern foot of the Zaō volcanoes, are shown in Table 4.

Table 4 Some physical properties of the ashes

Locality	Depth from the surface cm.	Soil color	True density	Apparent density	Porosity %	Field moisture capacity
Nanokahara, near Akiyamazawa, No. 1	10	Black brown	2.20	0.529	75.96	—
	30	Brown	2.50	0.650	74.00	—
Same as above, No. 2	10	Black brown	2.50	0.662	73.50	—
	30	Brown	2.60	0.752	71.08	—
Near the Nanokahara Primary School	10	Black brown	2.60	0.835	67.09	69.16
	30	Brown	2.60	0.752	71.08	50.48
	50	Brown	2.50	0.411	83.56	93.00
Near the Sukehirobori	10	Black brown	2.55	0.653	74.36	—
	30	Brown	2.60	0.832	68.00	—
Near the center of the fan	10	Black brown	2.50	0.650	74.00	—
	30	Brown	2.65	0.852	67.85	—

Methods: * True density is determined by the piknometer method
* Apparent density id determined by the true volume method useing a cylinder. * Porosity is by calculation.

As mentioned above, the true density is shown to be 2.20–2.65, but the brown volcanic ash is shown as a constant value of 2.50–2.65, and resembles the other soils or Kantō Loam (The Kantō Loam Res. Group, 1965). The apparent density of the dried soil is below 0.50, and the porosity is 82–83 percent in the Kantō Loam. This value of apparent density is shown as a very low character, however, the value of the volcanic ash in the Zaō area is above 0.50, and the average value of porosity as 70 percent. This value is not so low in comparison with the Kantō Loam.

Table 5 Some chemical properties of the volcanic ashes

Locality	Depth from the surface cm.	Soil color	Humus %	pH		Exchangeable cations mg.	
				KCl	H_2O	Ca	Mg
Nanokahara	20	Black brown	0.8	6.0	6.7	114.5	3.8
	100	Brown	1.0	5.6	6.0	98.6	11.6
Shimizuhara	12	Black brown	8.5	5.4	6.4	98.2	3.1
	52	Brown	3.4	5.2	6.1	34.0	3.9
	110	Black brown	2.5	5.6	6.6	85.2	4.6
	188	Brown	2.0	5.1	6.0	55.5	0.8
Kawarako	10	Dark brown	6.4	4.7	6.1	93.2	3.0
	30	Brown	4.0	4.5	5.5	62.3	2.9
	100	Yellow brown	1.1	4.4	5.4	34.5	4.0
Fubo-zan	10	Black brown	13.1	4.8	5.8	51.2	3.2
	50	Brown	7.1	5.4	5.7	46.0	3.0
	100	Brown	4.0	5.4	5.9	41.2	1.5
	120	Yellow brown	2.5	5.8	5.9	52.0	0.8
Sasaya, Hattcho-daira	10	Black brown	7.4	6.0	6.8	85.5	3.0
	50	Black brown	11.4	5.4	5.9	77.3	5.3
Miya	15	Black brown	3.5	6.2	6.5	93.7	2.7
	25	Black brown	3.5	6.4	6.8	93.1	2.7
	43	Dark brown	3.0	5.3	6.1	29.2	3.4

* pH—40 grams of dried volcanic ash are stirred with pure water or 1 normal solution of potassium chloride, and are measured by the glass electrode pH meter after one night.
* Humus—1 gram of volcanic ash is measured by Turin method.
* Exchangeable cations—By EDTA.

In the composition of grain size, the Kantō Loam becomes gradually rich in clay towards the lower layer, and the volcanic ashes of the Zaō area resemble the Kantō Loam in this respect. Lapilli and sand in the Zaō area are distributed within about 1 kilometer radius of Okama, and or within the area of the eastern edge of Sainokawara at the east. However, the volcanic ashes are found to be distributed beyond these areas and the grain size becomes finer as the distance increases from the origin.

The value of pH, humus, quantity of calcium and magnesium which are exchangeable cations of the volcanic ashes in chemical properties are shown in Table 6.

As shown in the Table 6, the volcanic ashes of the Zaō area include hum usat 1–11 percent, this being less compared with the average surface soil. And the soil acidity of the A-series volcanic ash is pH 6.0–7.0 (H_2O), whereas that of the B-series volcanic ash is pH 5.0–6.0 (H_2O). This soil acidity resembles the soil acidity of the Kantō Loam. The acidity of the brown volcanic ash of the Kurikoma volcanoes is pH 4.8–5.7 (H_2O) and pH 4.2–5.1 (KCl), hence the soil acidity in the Zaō area is nearer to neutrality in comparison with that of the Kurikoma area. Such a value of soil acidity which approaches neutrality is caused by the contents of plagioclase as shown under the microscope. Namely, the exchangeable calcium

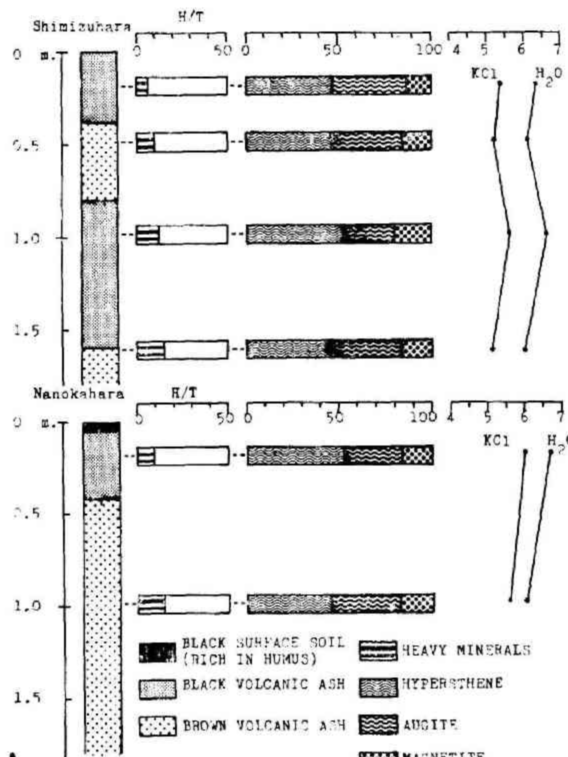

Fig. 36 Heavy Mineral Composition and pH Value of Voclanic Ashes in the Zaō Volcanic Area.

ion from plagioclase as the weathering effect shows a value near neutrality in the soil acidity, so the B-series volcanic ash of the Zaō area is characterized by the acidity of the soil compared with other volcanic ashes or other soil types. There is no remarkable difference in acidity of the soil when the layers are compared each other, but the acidity of the soil is inclined to become the lower value in the lower layer than in the upper layer.

Generally speaking, calcium in the soil is derived from plagioclase, and magnesium is from olivine, as a result of weathering. The volcanic ashes of the Zaō area are richer in calcium than magnesium in the ratio of the chemical composition, because the ashes are rich in plagioclase and poor in olivine. Especially, the A-series volcanic ash is very rich in calcium compared with the B-series volcanic ash.

As stated above, some differences in the characteristics are recognized between the A-series and B-series volcanic ashes. A pot culture test (Murayama, 1965) was performed by the writer from May to September in 1962 to know how different the plant's growth under the circumstances of no fertilizer, between the A-series and B-series volcanic ashes. The A-series volcanic ash for the test was collected at Nanokahara, and the B-series volcanic ash at Misumi, at the eastern foot of the Zaō volcanoes. The condition of the ash collecting localities was one where the influence by fertilzier or organic matter near the boundary of the distribution of the A-series and B-series volcanic ashes was the least. These ashes without fertilizer were put

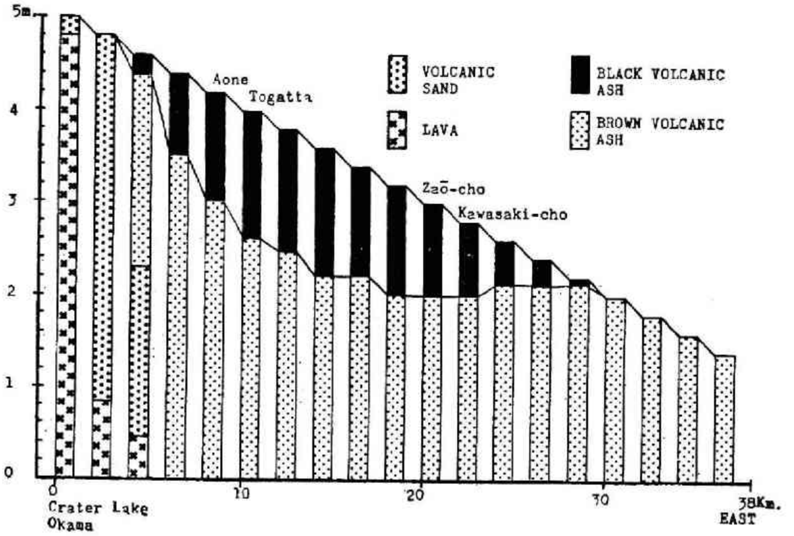

Fig. 37 Variation of Thickness of Black Volcanic Ash Layer in the Zaô Area.

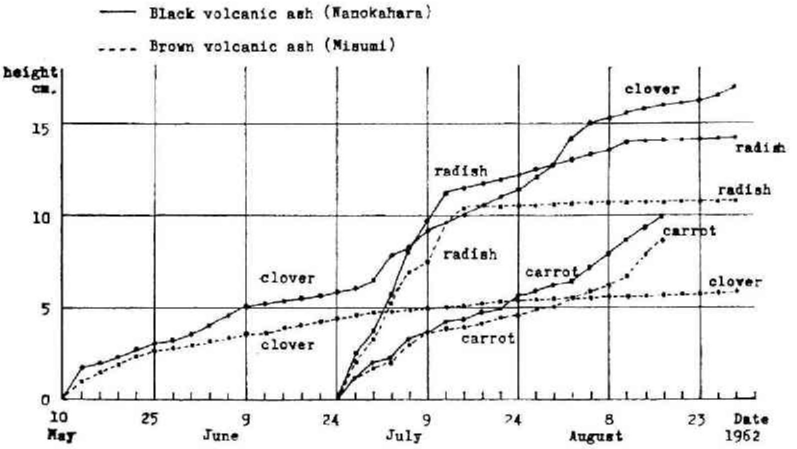

Fig. 38 Comparison of Plant Growth in Pot culture Test in the Zaô Volcanic Area.

into separate pots, and the plants such as clover, garden radish, carot, red turnip and cowpea etc. were seeded, and the plant growth under the same environmental conditions were observed. As the result, the plants in the A-series volcanic ash showed better growth compared with the ones potted with the B-series volcanic ash in general. Especially, the growth of the clover was much better in the A-series volcanic ash. Clover was seeded on May 10th, and it showed better growth in the A-series volcanic ash from germination time, and the growth after three weeks was remarkable. Such differences of plant growth between in the A-series and B-series volcanic ashes are supposed to be due to the differences in the mineral contents of the volcanic ashes. Namely, the A-series volcanic ash is richer in plagioclase than the B-series volcanic ash, and the soil acidity is near neutrality in pH value owing to the calcium derived from the plagioclase. Therefore, the plant growth of the clover is better, because it is suitable to such conditions as close to neutrality in soil acidity, and rich in calcium as nutritious substance. Also, regional differences in plant growth and crop yield etc. were recognized between the A-series and B-series volcanic ash areas.

3 The Narugo volcanic area

The black soil color of the A-series volcanic ash in the Narugo volcanic area is presumed to be due to the presence of colored minerals and humus.

The particles of the ashes are changed into clay state. There is recognized a few mineral fragments in the A-series volcanic ash compared with the volcanic ashes of the Zaō area.

The mineral components of the B-series volcanic ash are progressed in degree of leaching and the state of clay. The mineral fragments can not be seen in the B-series volcanic ash, and include humus at below 10 percent.

However, a few mineral fragments are recognized in the A-series volcanic ash, also include humus at more than 20 percent. Hence, the black soil color of the ash is presumed to have been derived from mainly humus, and colored minerals.

The acidity of the ashes is pH 3.9–4.9 (H_2O) and 3.4–3.9 (KCl). This soil acidity is very lower in value compared with other volcanic ashes investigated.

Table 6 Some characteristics of the volcanic ashes in the Narugo valcanic areas (Murayama, 1969c)

Localities	Depth from the surface cm.	Soil color	pH		Humus %	Mechanical analysis %			
			H_2O	KCl		Coarse sand	Fine sand	Silt	Clay
2	0–2	Black 7.5YR2/2	3.9	3.6	21.3	6.5	16.5	48.0	29.0
	2–10	Yellow brown 10YR5/6	4.0	3.9	21.7	13.6	40.5	26.4	19.5
5	0–8	Black 10YR2/1	4.8	3.7	21.2	10.5	16.0	12.5	61.0
	8–20	Dark brown 7.5YR3/4	4.7	3.9	9.1				
	20–50	Brown 7.5YR4/6	4.7	3.9	8.4				
	50-	Yellow brown 10YR5/6	4.9	3.4	0.9				

4 The Onikōbe volcanic area

The particles of the A-series and B-series volcanic ashes in the Onikōbe volcanic area are progressed in leaching, and no mineral fragments were recognzied in the ashes.

The A-series volcanic ash includes humus at 20–30 percent, this being rich compared with the Zaō, Bandai and Iwate volcanic ashes. However, the B-series volcanic ash of this area includes humus at 3–10 percent, this being less compared with the A-series volcanic ash.

The acidity of the ashes is pH 4–6 (H_2O) and pH 4–5.5 (KCl). This soil acidity resembles the soil acidity of the Kurikoma volcanic ashes.

Under the microscope, no mineral fragments are recognized in the specimens of the volcanic ashes. This reason is supposed that the weathering of the volcanic ashes has been progressed deeper by the subterranean heat.

Some characteristics of the volcanic ashes in the Onikōbe volcanoes are shown in the table.

Table 7 Some characteristics of the volcanic ashes in the Onikôbe volcanic areas. (Murayama, 1969c)

Localities	Depth from the surface cm.	Soil color	pH		Humus %	Mechanical analysis %			
			H_2O	KCl		Coarse sand	Fine sand	Silt	Clay
8	0- 7	Black brown 7.5YR3/2	4.95	4.08	28.35	9.0	7.5	18.5	65.0
	7-10	Dark brown 7.5YR3/4	5.25	5.50	17.70	8.5	6.5	18.5	66.5
	10-20	Light borwn 7.5YR5/8	4.99	4.62	9.81	10.0	7.5	6.5	76.0
	20-	Yellow brown 10YR5/6	5.95	5.07	3.21	4.5	3.0	2.5	90.0
10	0- 5	Black brown 7.5YR3/2	4.50	4.00	23.74	10.0	8.6	17.4	64.0
	5-	Yellow brown 10YR5/6	5.60	4.70	6.82	8.5	22.0	27.5	42.0

5 The Kurikoma volcanic area

The soil acidity of the brown volcanic ash in the Kurikoma volcanic area is pH 5–6 by the glass electrode pH meter with H_2O. The surface band which might be one centimeter or more than a few centimeters thick is rich in humus and shows blackish brown or dark brown colors. The subsurface layer which is referred to as the B-horizon is composed of the brown volcanic ash which is about one meter thick, and continues downwards to the underground mudflow materials. The soil colors of the subsurface layer and the matrix of the mudflow are of brown color which is shown to be 10YR4/6 by the Munsell soil color chart.

In the western areas at the foots of the volcanoes, the brown volcanic ash is changed into glei soil which shows a grayish white color due to the underground water. Some of glei soils are formed by melting water of the remaining snow in the southern part of the summit of the volcanoes. Rusty mottles are shown in the upper part of glei horizon. The relation between gleization and the remaining snow area is an interesting phenomenon.

Table 8 Some characteristics of the volcanic ash in the kurikoma volcanic area (Murayama, 1966b)

Localities of soil sampling	Depth from the surface	pH (by glass electrode)		Humus (%) (by Turin method)	Soil texture	Soil color (by Munsell system)
		H_2O	KCl			
1	0- 2	4.8	4.2	12.31	L	Dark brown 10YR3/3
	2- 8	5.6	5.1	6.02	C L	Brown 10YR4/6
	8- 25	5.5	4.6	0.63	C L	〃
	25- 50	5.6	4.4	0.32	C L	〃
2	0- 4	5.2	4.5	12.55	L	Black brown 10YR2/2
	4- 15	5.6	5.0	5. 3	C L	Brwon 10YR5/6
3	0- 14	5.0	4.4	8.52	L	Dark brown 10YR4/6
	14- 60	5.7	5.1	1.50	L	Brown 10YR4/6
	60- 95	5.6	4.4	0.33	C L	〃
4	0- 8	4.5	4.0	25.00	C L	Black brown 10YR2/2
	8- 15	5.0	4.2	14.50	C L	〃
	15- 40	6.0	5.5	1.51	L	Brown 10YR4/6
	40-	6.0	5.8	0.33	C L	〃
5	0- 15					Black brown 10YR2/2
	15-					Brown 10YR4/6
6	0- 30	5.3	4.9	12.50	L	Black brown 10YR2/2
	30- 57	5.6	5.1	1.50	L	Brown 10YR4/6
	57- 75	2.2	2.0	0.32	C L	Yellow gray 7.5Y6/1
	75-100	2.1	1.8	0.31	C L	Yellow gray 7.6Y5/1
7	0- 2					Black N2/1
	2- 3					Gray white N7/0
	3- 5					Gray black N3/0
	5- 9					Gray white N6/0
	9-					Brown 10YR4/6
8	0- 1					Black N2/1
	1- 11					Gray white N7/0
	11- 16					Black N2/1
	16- 33					Gray white N6/0
	33- 38					Black N2/1
	38-					Brown 10YR4/6

The mineral components of the brown volcanic ash are progressed in degree of weathering and the state of clay. Hence, very fine mineral fragments can be recognized under the polarized microscope of large magnification. However, mineral fragments can not be recognized in the glei soil.

Some remarins of straw-rope pattern pottery of prehistoric age were found from the upper layer of the brown volcanic ash about 15 centimeters below the surface at the southern foot of the volcanoes. In judgement of such a fact, the upper layer of the brown volcanic ash was deposited by the volcanic activities during the Jōmon culture era or befor this era.

Some characteristics of the volcanic ashes are shown in the table.

6 The Iwate volcanic area

The value of pH, humus, quantity of calcium and magnesium which are exchangeable cations of the volcanic ashes are shown in the tables.

As showed in the tables, the volcanic ashes of the Iwate volcanic area include humus at 1–14 percent, this being less compared with the average surface soil. And the soil acidity of the volcanic ashes is pH 5.2–6.8 (H_2O) and pH 4.1–6.5 (KCl). Such a value of soil acidity which approaches neutrality is caused by the contents of plagioclase as shown under the microscope. Namely, the exchangeable calcium ion from plagioclase as the weathering effect shows a value near neutrality in the soil acidity. There is no remarkable difference in acidity of the soil when the layers are compared with each other. Generally speaking, calcium in the soils is derived from plagioclase, and magnesium is from olivine, as a result of alteration. The volcanic ashes of this area are richer in calcium than magnesium in the ratio of the chemical composition, because the ashes are rich in plagioclase and poor in olivine.

The body of the A-series volcanic ash will normally contain, therefore, particles of fresh and unweathered mineral, partially decomposed particles furnish a reserve of mineral elements which are slowly made available for plant use by a continuation of the weathering processes.

The mineral elements in the volcanic ashes can be absorbed by plants only when they are included in the soil solutions. The B-series volcanic ash is reduced to this state by complicated weathering processes which disintegrate and decompose them into smaller and smaller particles. The brown soil color of the B-series volcanic ash is due to different forms, degree of hydration, and intensities of the oxides of iron which exist as thin coatings or stains upon the ash grains.

The specimens of the volcanic ashes examined under the microscope are mainly composed of plagioclase, augite, hypersthene and magnetite. The most predominant mineral is plagioclase.

The mineral crystals of the A-series volcanic ash are not so advanced in degree of leaching. A large size mineral fragment measures about 0.8 millimeters in long diameter. The mineral fragments of the B-series volcanic ash are progressed in degree of leaching and in the state of clay, however, small fragments of plagioclase are recognized. It takes a prismatic or granular form which is about 0.3 millimeters in length or diameter. The ratio of the mineral fragments in the B-series volcanic ash is smaller compared with that in the A-series volcanic ash. Almost

Table 9 Some Characteristics of the Volcanic Ashes in the Iwate Volcanic Area
(Murayama, 1966d)

Localities	Depthe from the surface (cm)	Soil color (by Munsell system)	pH (by glass) electrode		Mechanical analysis (by ASK elutriation) %				Soil texture	Humus %	Exchangeable bases mg./100 g.	
			H_2O	KCl	Coarse sand	Fine sand	Silt	Clay			CaO	MgO
4	0-42	Black brown 10YR2/3	6.4	6.0	4.3	22.7	41.8	31.2	L	6.4		
	42-48	Dark brown 10YR3/3										
15	0-35		6.1	5.4	28.7	34.3	31.2	5.8	L	11.6	334	39
	35-51		6.6	5.8	9.9	38.9	39.1	12.1	L	12.1	431	54
	51-70		6.6	5.8	18.5	55.8	19.4	6.3	S L	7.6	291	39
	70-		6.7	6.0	10.3	60.6	21.3	4.8	S L	7.1	362	34
27	0-20	Black 7.5YR 1/1	5.9	5.0	23.9	30.6	39.5	6.0	L	8.2	312	43
	20-71	Yellow brown 10YR 5/8	6.3	5.3	10.8	47.2	38.2	3.8	L	1.1	401	8
	71-	Gray yellow brown 10YR 5/4	6.6	5.5	31.3	31.3	24.2	13.2	L	1.5	445	194
30	0-20	Black brown 7.5 YR	5.2	4.1	60.1	20.0	12.0	7.9	S L	4.6	101	11
	20-	Brown 7.5YR 4/6	5.8	4.7	46.0	36.5	12.1	5.4	S L	1.0	164	35
31	0-47	Black brown 7.5YR 2/2	5.4	4.6	13.3	28.4	49.6	8.7	SiL	9.3	51	18
	47-	Brown 7.5YR 6/8	5.9	4.5	5.3	35.8	32.9	26.0	C L	1.4	123	67
34	0-12	Black 10YR 1/1	6.8	6.5	22.6	34.6	37.7	5.1	L	14.1	1,225	24
	12-70	Dark brown 10YR 3/3	6.7	6.3	18.0	55.3	22.5	4.2	S L	6.1	446	45
	70	Brown 10YR 4/4	6.7	6.3	37.2	50.0	10.1	2.7	L S	2.3	211	38

all of the mafics in the ashes consist of augite, hypersthene and magnetite etc. However, the A-series volcanic ash also includes olivine.

7 The Yake-yama volcanic area

Some characteristics of the ashes were determined in order to know the distinction between the upper and lower parts of the ash layer, and the difference between the ashes of this area and the other areas investigated, etc.

The volcanic ashes of the Yake-yama volcanic area include humus at 1–13 percent, this being less compared with the average surface soil. And the soil acidity of the volcanic ashes is pH 5.5–6.0 (H_2O) and pH 4.7–5.8 (KCl).

A black top soil horizon has been assigned to an A-horizon, based upon the assumption that the soils may have resulted through transformation of the top of the parent materials, in the process of soil formation, which differing from normal geological process of deposition. The "humic volcanic ash soil" on the Pleistocene tephra layer, which is the most common type of the black soil in Japan implies that volcanic ash showering at times fell out through the process of concentration of humus. Even in the case of non-volcanic humic soils, the formation may primarily be due to the accumulation of atmospheric dust from various sources along with the mass-wastes from nearby slopes (Kobayashi, 1967).

According to the report by Hasegawa (1967), from 3rd to 4th of February in 1966, the snow covering Takada City and its vicinity in Niigata Prefecture was stained with a pale grayish fine substance. In this fact, the ancient dunes along the coast of the Japan sea, which consist of loess-like sand are supposed to transport from a sandy desert. It is assumed that the formation of these dunes had some connection with the loess which was supplied from an altitude of several thousand meters. This kind of supply of loess had connection also with the formation of recent dunes, soil and loam.

As stated above, in the cases of the volcanic regions investigated, the black volcanic ash in the top soil horizon and a parting layer of the black volcanic ash, are supposed to accumulation as atmospheric dust.

However, the black volcanic ash which accumulated in the volcanic areas is changed into the state of clay, and is transformed to vermiculite with aluminum from montmorillonite in the interlayer position. Aluminum is more intensely fixed in the interlayer position of the clays in the A-horizon than the lower (Masui and Shoji, 1967).

At the result of heavy mineral analysis, augite, hypersthene and magnetite etc. were found. However, there is no remarkable distinction between the A-series and B-series volcanic ashes. Hence, these ashes are presumed to have been derived from similar parent rocks.

8 The Hachiman-tai volcanic area

The specimens of the black and brown volcanic ashes exmained under the microscope are mainly composed of plagioclase, augite, hypersthene and magnetite etc. The most predominant mineral is plagioclase. It is commonly 0.2–0.4 millimeters in length.

As showed in the table, the volcanic ashes of the Hachiman-tai volcanic area include humus at 3.4–20.5 percent. This being more compared with the percentages of humus in the Yake-yama and Iwate volcanic areas. And the soil acidity of the volcanic ashes is pH 5.2–5.8 (H_2O) and pH 9.4–5.6 (KCl).

A parting layer of the black volcanic ash in the brown volcanic ash layer is found on the flank of Hachiman-tai. The upper layer of the brown volcanic ash which was deposited on the black parting layer is correlated to the brown volcanic ash which yielded the remains of pottery in the last stage of the Jōmon culture era. This brown volcanic ash layer may had been deposited during the Atlantic and Sub-boreal periods. It is thought that the parting layer of the black volcanic ash was deposited under a natural environment of cold climate, and this may explain the unprogressed leaching.

Table 10 Some characteristics of the volcanic ashes in the Hachiman-tai volcanic area. (Murayama, 1968b)

Localities	Depth from the surface (cm)	Soil colors	PH (by glass electrode)		Huumus %
			H_2O	KCl	
1	0–5	Black brown 7.5 YR2/2	5.3	5.1	20.5
	5–12	Brown 7.5 YR 4/3	5.7	5.5	10.4
	13–15	Black brown 7.5 YR 3/2	5.4	5.2	5.5
	30–40	Brown 7.5 YR 4/6	5.8	5.6	3.4
4	0–5	Black brown 7.5 YR 2/3	5.5	5.3	18.4
	6–10	Yellow brown 10 YR 5/8	5.3	5.1	7.6
	20–25	Yellow brown 10 YR 5/6	5.2	5.0	6.6
9	0–10	Black brown 10 YR 2/3	5.2	4.8	18.7
	30–40	Yellow brown 10 YR 5/6	5.4	5.2	6.7

9 The Hakkōda volcanic area

The specimens of the volcanic ashes exmained under the microscope are composed of plagioclase, augite, hyperthsthene and magnetite etc. The most predominant mineral is plagioclase.

The upper part of the volcanic ash layer contents raw humus. However, there are some distinction in the characteristics of humus between podzol and volcanic ash layer (Turner and Schnitzer, 1962).

As showed in the table, the volcanic ash of the surface includes humus at 12–30 percent, this being rich compared with the other volcanic ashes investigated. This humus is derived from mainly plant substances.

The soil acidity of the volcanic ashes is pH 4.9–5.5 (H_2O) and pH 3.6–5.3 (KCl). These values of soil acidity are slightly acid. It may be due to organic acid from humus.

Black and blackish brown colors in the surface soil in this area usually but not always, denote a considerable content of organic matter. However, the black soil color of the A-series volcanic ash in the volcanic areas investigated is due to colored minerals and black glasses etc. This point is remarkable difference between the surface soil of the Hakkōda volcanoes and the A-series volcanic ash of the other areas. The surface soils in this area are prevailingly unlike their subsoils in color.

Table 11 Some characteristics of the volcanic ashes in the Hakkōda volcanic area

Localities	Depth from the surface cm.	Soil colors	pH		Humus %
			H_2O	KCl	
1	0-3	Black brown 7.5 YR 2/2	5.2	4.9	12.5
	15-20	Brwon 7.5 YR 4/3	5.5	5.3	3.5
5	0-2	Black 2.5 Y 2/0	—	—	30.2
	5-10	Gray N 5/0	5.1	3.7	6.3
	15-18	Yellow brown 10 YR 5/6	4.9	3.6	1.6
8	0-13	Black brown 7.5 YR 2/3	5.3	5.1	—
	20-25	Yellow brown 10 YR 5/6	5.4	5.1	—

V Conclusion

Generally speaking, the volcanoes on the back-bone mountains in the Northeastern Section of Japan, rest upon the eroded surface of basements

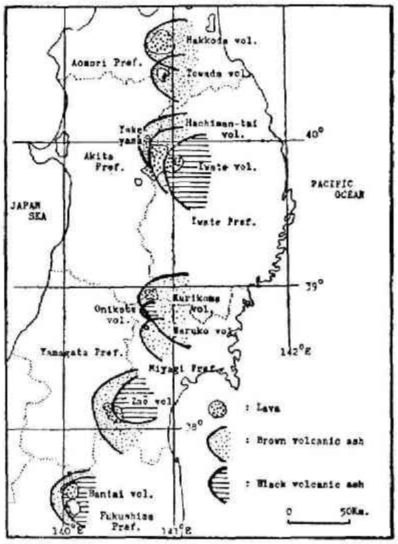

Fig. 39

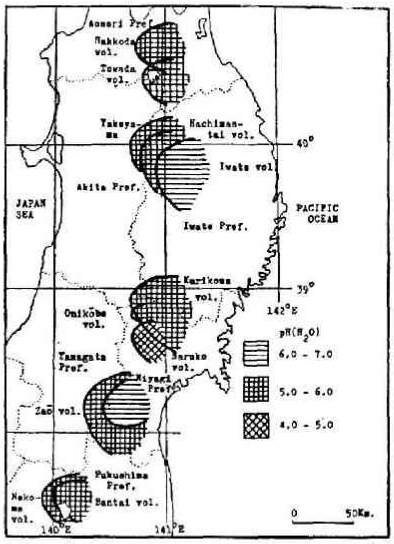

Fig. 40

Fig. 39 Distribution of Black and Brown Volcanic Ashes in the Areas Investigated. (Murayama 1969b)

Fig. 40 Showing the Average Values of pH (H_2O) of the Volcanic Ashes in the Areas Investigated. (Murayama, 1969b)

composed of granite, granodiorite, the Tertiary formations and lacustrine deposits etc. These volcanic bodies exhibit rough stratification produced by alternating sheets of lava and volcanics. The structure of the alternating sheets attests to alternating periods of explosive and quiet eruption.

After the volcanic bodies were formed, many volcanic explosions occurred and rushed down the mudflow materials towards the lower parts. Such as many mudflow areas were formed after the volcanic bodies were constructed.

The volcanic fragmental materials often accompany volcanic explosions from the explosion craters, and are subsequently deposited on the surface of the earth. One of the chief volcanic fragmental materials is volcanic ash. Ash showers have covered extensive area with enormous quantities of ash. Newly deposited ashes are generally blackish or grayish in color, but turn brown as a result of weathering and oxidation etc.

The stages of deposition of the volcanic ashes in the Northeastern Section of Japan can be divided into two stages in principle. Namely, (1) The first stage – This stage is the period of deposition of the B-series volcanic ash (brown or yellowish brown color) in the volcanic area. The lower part of the volcanic ash layer covers the lower terrace plains, and is correlated to the Tachikawa Loam

Table 12 Correlation

	Period	Kantô region	Volcanic ashes in the Northeastern Section of Japan	Terrace plains and mudflows in the Northeastern Section of Japan
Holocene	Historic time		A-series volcanic ash (Black, blackish gray, blackish brown soil colors) (Okama volcanic ash etc.)	Ura-bandai mudflow, Yake-bashiri lava flow
	Subatlantic	Coastal plains	The upper part of B-series volcanic ash (Dark brown or brown soil color)	Recent fluviatile deposits, coastal plains
	Subboreal	Yûraku-cho layer Ekoda second layer	B-series volcanic ash which includes strawrope pattern potteries with pinnate pattern in Jomon culture age	Shimomachi, Ayashi, Kawasaki, Takehara, Onikôbe, Iwamochi, Nagabukuro etc. terrace plains
	Atlantic	Yûraku-chô layer	B-series volcanic ash (Yellowish brown or brown soil color) (Early stage in Jômon culture age)	
	Boreal Preboreal	Yûraku-chô layer Ekoda first layer	Black parting layer in the B-series volcanic ash, Dark brown or brown volcanic ash layer in lowland	
Pleistocene	Würm	Tachikawa loam	B-series volcanic ash (Yellowish brown soil color) (Nagano, Wakare etc. volcanic ashes)	Nagano, Nôjô, Nakamachi, Hara, Myofujô, Kôma Shizukuishi terrace plains
		Musashino loam	Yellowish brown volcanic ash (Hirasawa etc. volcanic ash)	Kamimachi, Omori, Daigaku-nojô, Shibutami, Akasaka terrace plains, Kawarako, Koiwai, Takizawa mudflows
	Riss	Shimosueyoshi loam	Medeshima volcanic ash etc. (Brown soil color)	Dainohara, Sanjô, Takahata, Medeshima terrace plains etc.
	Mindel	Tama loam	Koeji volcanic ash etc. (Reddish brown or brown soil color)	Aoyama-chô, Tairadate, Matsu-kawa, Ōmoriyama mudflows etc.

Layer in the Kantō Region. The remains of Jōmon culture pottery of prehistoric age were found from the upper layer of the B-series volcanic ash. (2) The second stage – This stage is the period of deposition of the A-series volcanic ash (black or blackish gray color) on the B-series volcanic ash layer. This A-series volcanic ash is supposed to have accumulated since the last stage of the Jōmon culture, and mainly during historic time.

In the volcanic areas investigated, the color of the volcanic ashes is a conspicuous feature of the landscape. Important as that is to geography, it is not its only significance. Volcanic ashes range in color through a wide variation of shades or tints from white to black. Among the commonest colors are dull shades of brown, or yellow. The alteration of volcanic ashes occurs in and around the individual particles of the ashes. Such as particles that have been leached, also iron which is included in the particles of the ashes as a chemical composition has been changed by oxidation, and thus the ash will exhibit a brown soil color system. The black colored volcanic ash of which has an average grain size may be changed into brown colored volcanic ash after a period of more than 1,000 years in the volcanic areas of the Northeastern Section of Japan. Such as, two stages of chemical weathering may be observed and differentiated in a vertical cross section of the volcanic ash layer.

Recent volcanic ashes include fresh mineral fragments such as plagioclase, hypersthene, augite and magnetite etc. Namely, the A-series volcanic ash includes mineral fragments of size larger than that of the B-series volcanic ash. Especially, the A-series volcanic ash of the Zaō volcanoes is rich in plagioclase fragments compared with the ashes of other volcanoes. Also, the pH value is near neutrality.

The black parting layer in the B-series volcanic ash layer formed mainly by the difference in degree of leaching under the environment of the cold climate. The parting layer may have been deposited during the cold climate of Preboreal and Boreal periods. Because of the fact that climate is an important factor in weathering. And, the volcanic ashes as a whole are much leached comparatively at the foots of the volcanoes than the volcanic ashes of the higher latitudes.

Temperatures and precipitations influenced to degree of hydration, and intensities of the oxides of iron which exist as thin coatings or stains upon the particles of volcanic ashes. Soil color of the volcanic ash has relation to these factors. And, the color of volcanic ash changes, not only from place to place but also from the surface downward and from one time to another. Surface soils, in some volcanic regions, are prevailingly unlike their subsoils in color.

References

Beaty, C.B. (1963): Origin of Alluvial Fans, White Mountains, California and Nevada, Ann. Ass. American Geogr. **53** 516–535

Blackwelder, E. (1928): Mudflow as a Geologic Agent in Semiarid Mountains, Bul. Geol. Soc. Amer. **39** 469–470

Chiba, T. (1961): Petrology of Zaô Volcano (in Japanese), Jour. Japan Ass. Min. Petr. Econ. Geol.. (Ganseki, Kôbutsu, Kôshô Gakkai-shi) **46** 73–82

Cotton, C.A. (1944): Volcanoes as Landscape Forms, Whitcombe and Tombs Ltd. 416 ps.

Furuya, T. (1965 a): The Topography of the Bases of the Bandai and Necoma Volcanoes, Sci. Rep. Tohoku Univ., Seventh Series **14** 87–100

——— (1965 b): Geomorphological Developments of the Eastern Foot of the Zaô Volcanoes and their Environs (in Japanese), Geogr. Rev. Japan (Chirigaku-Hyoron) **38** 57–73

Glinka, K.D. (1940): The Great Soil Groups of the World and their Development 10–140

Gohara, Y. (1963): Late Pleistocene Tephrochronology of Kyushu Region, Japan (in Japanese), Quat. Res. **3** 123–136

Hase, H. (1963): Marine Terraces of the Tsugaru Peninsula, Aomori Prefecture, Ann. Tohoku Geogr. Ass. **15** 146–152

Hasegawa, T. (1967): Loess that Fell in Takada City, Niigata Prefecture (in Japanese), Jour. Geol. Soc. Japan **73** 463–467

Hayakawa, N. (1951): On the Volcanic Activities in the Upstream Area of the Kakkonda River, Iwate Prefecture, Jour. Japan. Ass. Min. Petr. Econ. **35** 80–86

———, Funayama, Y., Saito, K. and Kitamura, M. (1954): Neogene Formation on the Area between the Back-bone Mountains and the Western Part of the Kitakami Mountains in Iwate Prefecture (in Japanese), Bul. Tohoku Min. Ass. **10** 10–14

Ichimura, T. (1951): Geological Investigations on the Zaô Volcanoes, I, Goshiki-dake, A Central Cone of the Zaô Proper, Bul. Earthq. Res' Inst. **29** 327–339

——— (1953): Geological Investigation on the Zaô Volcanoes, II, Aoso Volcano, Bul. Earthq. Res. Inst. **31** 129–149

——— (1955): Geological Investigations on the Zaô Volcanoes, III, Byobu Volcano, Bul. Earthq. Res. Inst. **33** 593–629

Ikeda, T. (1942): Geology of the Narugo Area (in Japanese), Graduation Thesis of Tohoku University.

Ishida, T., (1965): Quaternary Geology and Geomorphology of Sendai and its Environs (3) (in Japanese), Quat. Res. **4** 13–21

Ishizuka, K. (1948): Soil in the Reclaimed Land at the Foot of the Iwate Volcanoes (in Japanese), Land Reclamation Bureau, Ministry of Agriculture and Forestry 1–40

Iwai, J. (1951): Pleistocene Formation in the Eastern Area of Aomori Prefecture (in Japanese), Sci. Rep. Dept. of Geology and Paleontology, Tohoku Univ. **40** 1–31

Jenny, H. and **Overstreet, R.** (1939): Cation Interchange between Plants Roots and Soil Colloids, Soil Sci. **47** 257–272

Kato, I. and **Shimada, I.** (1953): On the Geology of Green-tuff Area at the Western Foot of the Kurikoma Volcanoes, and Lacustrine Deposits of the Onikôbe Basin (in Japanese), Jour. of the Japan. Ass. Min. Petr. Econ. Geol. **37** 180–190

Katsui, Y. (1955): Petrological Consideration on Welded Tuff in the Around of the Onikôbe Caldera (in Japanese), Jour. Japan. Ass. Min. Petr. Econ. Geol. **39** 190–194

Kantô, Loam Res. Group (1965): Kantô Loam (in Japanese) 269–278

Keller, W.D. (1957): The Principles of Chemical Weathering, Lucas Brothers Publishers 5–6

Kitagaki, N. (1953): The Life and Theory of Williams (in Japanese), Seidô-sha 50–95

Kobayashi, F. (1929): Volcanoes (in Japanese), Nankô-sha 305–306

Kobayashi, T. (1951): Regional Geology in Japan, General Remarks (in Japanese), Asakura-shoten 221–223

Kobayashi, J. (1960): The Study on the Average Values in Analysis of River Waters and its Characteristics in Japan (in Japanese), The Research of Agriculture **48** 63–

106

Kobayashi, K. (1963): Pleistocene Tephras in the Central Region of Japan (in Japanese), Quat. Res. **3** 110–122

——— (1967): Preliminary Discussion on the Deposition Process of the Black Humic Soils in Japan (in Japanese), Pedologist **11** 15–24

Lenin Acad. Agr. Sci. USSR, 1949: The Situation in Biological Science 145–230

Masui, J. and **Shoji, S.** (1967): Some Problems on Clay Minerals of Volcanic Ash Soil, Pedologist **11** 33–44

Meteorological Bureau, (1959): Volcanic Explosion Recrods in Japan (in Japanese) (Mimeograph)

Mihara, R. (1955): Volcanic Activities of the Zaô Volcanoes from View Point of the Historical Records (in Japanese), The Research Reprots of the Zaô Mountains, Miyagi Prefectural Office 70–71

Minato, M. and **Ijiri, S.** (1958): Japan Islands (in Japanese), Iwanami-Shoten 89–92

Miyagi-ken High School's Science Study Organization, 1963: Gology and Geological History in Narugo Area (in Japanese), Earth Sci. Rep. **1** 18–21

Mizuno, Y. (1958): The Topography of the Okinajima Mudflow Area, Ann. Tohoku Geogr. Ass. (Tohoku Chiri) (in Japanese) **11** 22–24

——— (1960): Geomorphological Development in the Surrounding Area of the Iwate Volcanoes (in Japanese), Ann. Tohoku Geogr. Ass. **12** 71–76

——— (1961): Geomorphology of Volcanic Mudflow in the Area around Iwaki volcano (in Japanese), Ann. Tohoku Geogr. Ass. **13** 85–88

——— (1964): Topography of the Volcanic Mudflow at the Foots of the Zaô Volcanoes (in Japanese), Bul. Educational Faculty, Hirosaki Univ. **13** 23–32

Murayama, I. (1959): On the Movement of Rock Fragments from Byobu-dake in the Zaô Volcanoes, Saito Ho-on Kai Mus. Res. Bul. **28** 40–48

——— (1960): On the Distinction and Distribution of Volcanic Ashes in the Zaô Volcanoes and their Vicinities, Saito Ho-on Kai Mus. Res. Bul. **29** 18–24

——— (1964): Soil Erosion by Winds on the Eastern Foot of the Zaô Volcanoes, Saito Ho-on Kai Mus. Res. Bul. **33** 9–16

——— (1965): Deposited Period and Some Characteristics of the Volcanic Ashes in the Eastern Foot of the Zaô Volcanoes (in Japanese), Ann. Tohoku Geogr. Ass. **17** 50

——— (1966 a): Les Cendres Volcaniques Des Volcans Zao (in Japanese with French summary), Geogr. Rev. Japan **39** 591–605

——— (1966 b): Volcanic Ejecta of the Kurikoma Volcanoes, Saito Ho-on Kai Mus. Res. Bul. **34** 39–46

——— (1966 c): Glei Soil in the Remaining Snow Area of the Kurikoma Volcanoes, (in Japanese), Ann. Tohoku Geogr. Ass. **18** 38

——— (1966 d): Volcanic Ashes of the Iwate Volcanoes, Saito Ho-on Kai Mus. Res. Bul. **35** 29–41

——— (1968a): Volcanic Ashes on the Bandai Volcanoes, Pedologist **12–1** 13–24

——— (1968 b): Volcanic Ejecta in the Yake-yama and Hachiman-tai Volcanic Areas, Saito Ho-on Kai Mus. Res., Bul. **37** 19–33

——— (1969 a): Lacustirine Deposit of Volcanic Ash in the Katayama Geothermal Area (in Japanese), Ann. Tohoku Geogr. Ass. **21** 161

——— (1969 b): Volcanic Ashes in the Northeastern Section of Japan, Pedologist **13** 1–12

——— (1969 c): Quaternary Volcanic Ashes in the Narugo and Onikôbe Volcanic Areas, Quaternary Res. **8** 101–107

Nakagawa, H., Ogawa, S. and **Suzuki, Y.** (1960): Quaternary Geology and Geomorphology of Sendai and its Environs (1) (in Japanese), Quat. Res. **1** 219–227

———, **Ishida, T., Sato, J., Matsuyama, T.** and **Nanasaki, O.** (1963): Quaternary Geology and Geomorphology along the Upper Stream of the Kitakami River, Northeast Honshu, Japan, -Quaternary History of the Drainage Area of the Kitakami River (1)-, (in Japanese) Jour. Geol. Soc. Japan **69** 163–171

Nakamura, H. (1956): The Relationships between Geological Structure and Geothermy in the Onikôbe Circle, Miyagi Prefecture (in Japanese), Monthly Rep. Geol. Surv. Japan **10** 23–48

Nitobe, K. (1964): Marine Terraces in the Misawa Area, Aomori Prefecture (in Japanese) Ann. Tohoku Geogr. Ass. **16** 121–125

Omoto, K. (1964): Geomorphologic Development of the Onikôbe Basin, Miyagi Prefecture (in Japanese), Ann. Tohoku Geogr. Ass. **16** 61–70

——— (1966): Geomorphological Development of the Narugo Basin, Miyagi Prefecture, Northeastern Japan (in Japanese), Geogr. Rev. Japan **39** 521–537

Onuki, Y., Mii, H., Shimada, I., Takeuchi, S., Ishida, T. and **Saito, T.** (1963): Late Quaternary History of the Tsugaru Jusan-ko District, Aomori Prefecture (in Japanese), Sci. Rep., Dept. of Geology and Paleontology, Tohoku Univ. **58** 1–36

Sakai, G., Miyagi, K., Iwai, T. and **Mizuno, Y.** (1967): The Geology and Underground Resources in Aomori Prefecture (in Japanese), Rikuô Press Co. 20–26

Sharp, R.P. and **Nobles, L.H.** (1953): Mudflow of 1941 at Wrightwood, Southern California, Bul. Geol. Soc. Amer. **64** 552

Serizawa, C. (1963): Archaelogical Materials from Volcanic Ash Layers, Quat. Res. **3** 67–71

Shoji, S., (1950): The Investigations of the Source of Underground Water in Nanokahara, Miyagi Prefecture, Rep. Miyagi Pref. Office

Tanabe, K. (1960): Geomorphography of the Northern Half of Inawashiro Basin with Relation to the Changes of Lake Level, Sci. Rep. Tohoku Univ., Seventh Series **9** 67–80

Tayama, R. (1933): Geomorphological Investigations on the Kitakami Mountains, I, River Terrace, A, River Terrace of Sendai City and its Environs (**1**) (in Japanese), Quat. Res. **1** 219–227

Toya, H. (1962): Some Physio-geographical Considerations on the Volcanogenous Deposit, Akatsuchi (in Japanese), Ann. Tohoku Geogr. Ass. **14** 85–91

Turner, R.C. and **Schnitzer, M.**, (1962): Thermogravimetry of the Organic Matter of a podzol, Soil Sci. **93** 225–232

Tsujimura, T. (1942): Fault Topography (in Japanese), Kokin-sho-in 137

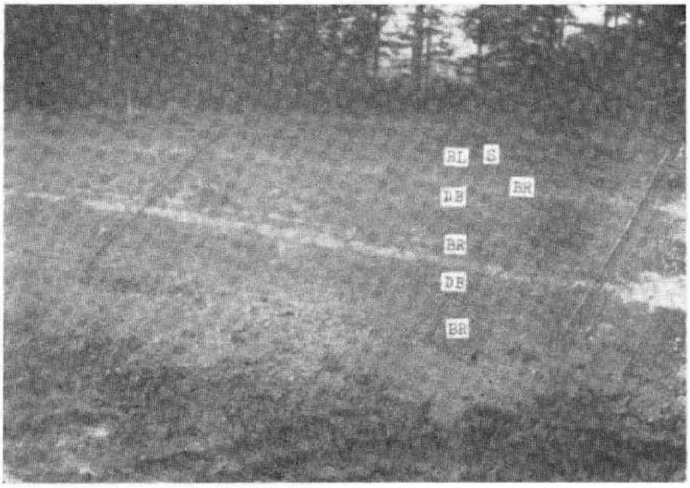

Fig. 41 A Volcanic Ash Layer at the Southern Side of the Takizawa Station, the Southeastern Foot of the Iwate Volcanoes.
S: Surface soil BL: Black volcanic ash. BR: Brwon volcani ash layer DB: Dark brown volcanic ash layer (Murayama, 1966b)

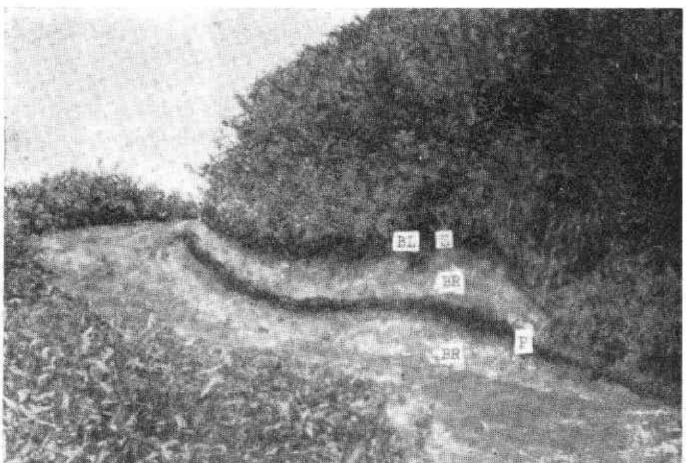

Fig. 42 A Volcanic Ash Layer at the Southwestern Foot of Kamakura-mori near the Amihari Spa in the Iwate Volcanic Area.
BL: Black volcanic ash layer S: Surface soil BR: Brown volcanic ash layer P: Parting layer of the black volcanic ash (This parting layer is thought to have been deposited during the cold climate of the Preboreal and Boreal period.) (Murayama, 1966d)

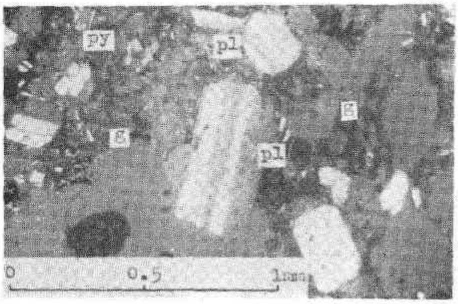

Fig. 43

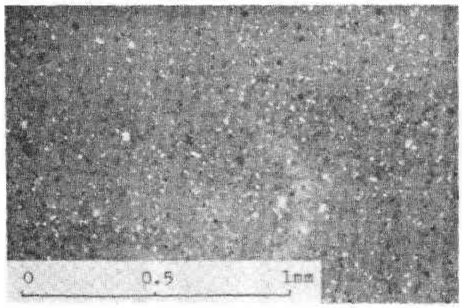

Fig. 44

Fig. 43 Lava at the Summit of the Kurikoma Volcanoes (by crossed nicol under the microscope). pl. plagioclase, py: pyroxine, g: groundmass

Fig. 44 Showing Advanced Leaching Degree of the Brown Volcanic Ash in the Kurikoma Volcanoes (Murayama, 1966b)

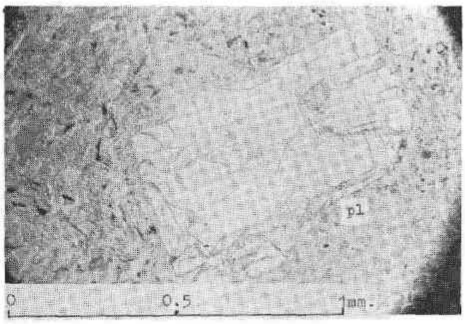

Fig. 45

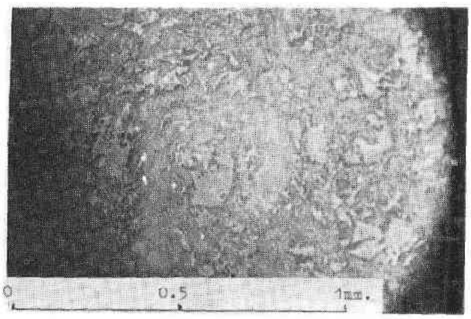

Fig. 46

Fig. 45 Showing the Minerals in the Lava of Yake-yama (Central cone), pl: plagioclase

Fig. 46 Weathered Lava in the Solfataric Area of Yake-yama.

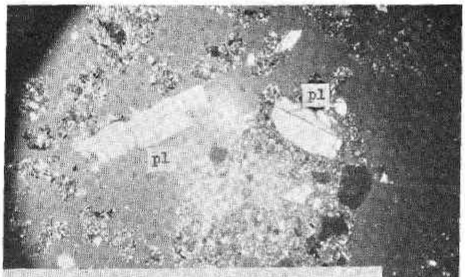

Fig. 47

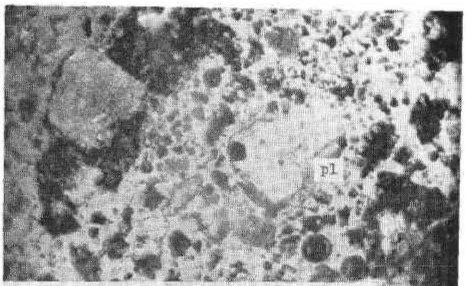

Fig. 48

Fig. 47 Showing the Minerals of the Brwon Volcanic Ash of the Yake-yama.

Fig. 48 Showing the Minerals of the Black Volcanic Ash at Higashi-hachiman-tai (Murayama, 1968b)

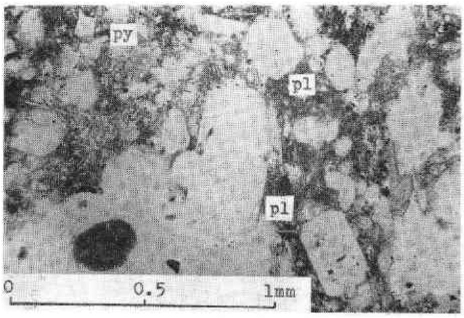

Fig. 49

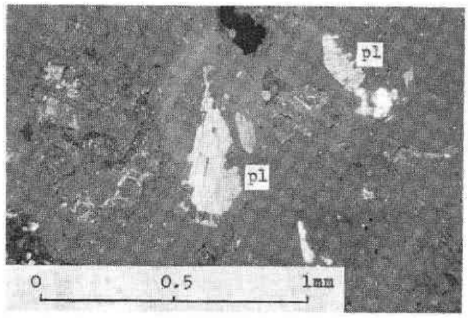

Fig. 50

Fig. 49 Showing the Minerals in the A-series Volcanic Ash at Nanokahara in the Zaô Volcanoes.

Fig. 50 Showing the Minerals in the B-series Volcanic Ash at Misumi in the Zaô Volcanoes.

Fig. 51

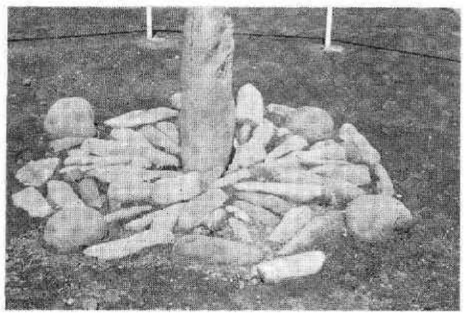

Fig. 52

Fig. 51 Welded Tuff along the Oirase-river, Towada.

Fig. 52 Stone-circle in the Upper Layer of the B-series Volcanic Ash at Oy, Akita Prefecture.

Abstract

Because of the fact that climate is an important factor in soil formation, there is a notable correlation between the world distribution of the major soil types on the one hand, and that of the great climatic regions with their characteristic vegetational associations, on the other. The relationship is most clearly seen in the distribution of the maturely developed soils. Such normal soils show great uniformity within a given set of environmental conditions regardless of the parent materials from which they are derived, and they show likewise great differences in character under different climatic environments, even though their parent materials may have been similar.

The soils in the volcanic regions are mainly developed from the volcanics (volcanic ejecta). The characteristics of volcanic ashes are closely related with volcanics as a soil parent in the volcanic regions.

Colors of volcanic ashes when accumulated as the result of an explosion in Quaternary are black or gray owing to the colored minerals and black glass etc. (Murayama, 1966a). And climate influencess soil formation from the volcanic ashes both directly and indirectly. Directly it affects the weathering of volcanics, the percolation of water through the volcanic ashes, and the work of the gradiational agents. Climate also affects the alteration of the volcanic ashes through its seasonal variations in temperature and rainfall. Prevailing high temperatures promote rapid chemical change in the volcanic ashes, and cold slows it down. Alternating seasons of rain and drought cause volcanic ashes to develop color and composition different from those of volcanic ashes of continuously rainy regions.

The mineral elements of the volcanic ashes are reduced by complciated weathering processes which disintegrate and decompose them into smaller and smaller particles. In such a phenomenon, the particles of volcanic ashes are changed into the state of clay, and show a brown color system, and certain soil characteristics in consequence of the degree of leaching. The body of the volcanic ashes will normally contain, therefore, particles of fresh and unweathered minerals, partially decomposed particles, and others grading down into the colloidal state. The larger particles furnish a reserve of mineral elements which are slowly made available for plant use by a continuation of the weathering processes. The brown color system of the volcanic ashes is due to different forms, degree of hydration, and intensities of the oxides of iron which exist as thin coating or stains upon the ash grains. The mineral elements in the volcanic ashes can be absorbed by plants only when they are included in the soil solutions.

It has been noted previously that the minerals of the volcanic ashes are leached by some factors as of temperature, precipitation and others. The black or gray volcanic ashes owing to colored minerals are more advanced in weathering and leaching under the natural environment of high temperature, and cold slows it down. Hence, fresh volcanic ash is presumed to have not been so advanced in weathering and leaching in the natural environment of low temperature during the ice ages.

The volcanic ashes deposited at the foots of the volcanoes in Northeastern Japan, consist of two main classes, one of the black volcanic ashes, and the other of brown color. Generally speaking, the mineral components of the brown volcanic ash are progressed in degree of leaching and the state of clay. The writer presumes that the black volcanic ash is changed into the brown volcanic ash by leaching. Concerning phenomenon, some different characteristics of the volcanic ashes are shown in this region.

In this thesis is described the characteristics of volcanics, especially the volcanic ashes as a result of weathering from the view point of locality and paleoclimatology during the ice age at the foots of the back-bone mountains in the Northeastern Section of Japan, for instance, the Bandai, Zaô, Narugo, Onikôbe, Kurikoma, Iwate, Hachiman-tai and Hakkôda volcanoes etc.

The stages of deposition of the Quaternary volcanic ashes in the areas investigated,

can be divided into two stages in principle. Namely, (1) The first stage – This stage is the period of deposition of the B-series volcanic ash (brown or yellowish brown color) in the volcanic area. The lower part of this volcanic ash layer covers the lower terrace plains, and is correlated to the Tachikawa Loam Layer in the Kantô Region. The remains of Jômon culture pottery of prehistoric age were found from the upper layer of the B-series volcanic ash. (2) The second stage – This stage is the period of deposition of the A-series volcanic ash (black or blackish gray color) on the B-series volcanic ash layer. This A-series volcanic ash is supposed to have accumulated since the last stage of the Jômon culture, and mainly during historic time.

The black inner layer (parting layer) in the B-series volcanic ash layer formed mainly by the difference in degree of weathering under the environment of the cold climate. The black inner layer may have been deposited during the cold climate of Preboreal or Boreal period.